

INHIBITORS OF INTERLEUKIN-1 $\beta$  CONVERTING ENZYMETECHNICAL FIELD OF THE INVENTION

5 The present invention relates to novel  
classes of compounds which are inhibitors of  
interleukin-1 $\beta$  converting enzyme ("ICE"). The ICE  
inhibitors of this invention are characterized by  
specific structural and physicochemical features. This  
invention also relates to pharmaceutical compositions  
10 comprising these compounds. The compounds and  
pharmaceutical compositions of this invention are  
particularly well suited for inhibiting ICE activity  
and consequently, may be advantageously used as agents  
against interleukin-1 ("IL-1") mediated diseases,  
15 including inflammatory diseases, autoimmune diseases  
and neurodegenerative diseases. This invention also  
relates to methods for inhibiting ICE activity and  
methods for treating interleukin-1 mediated diseases  
using the compounds and compositions of this invention.

20 BACKGROUND OF THE INVENTION

Interleukin 1 ("IL-1") is a major pro-  
inflammatory and immunoregulatory protein that  
stimulates fibroblast differentiation and  
proliferation, the production of prostaglandins,  
25 collagenase and phospholipase by synovial cells and  
chondrocytes, basophil and eosinophil degranulation and

neutrophil activation. Oppenheim, J.H. et al,  
Immunology Today, 7, pp. 45-56 (1986). As such, it is  
involved in the pathogenesis of chronic and acute  
inflammatory and autoimmune diseases. IL-1 is  
5 predominantly produced by peripheral blood monocytes as  
part of the inflammatory response and exists in two  
distinct agonist forms, IL-1 $\alpha$  and IL-1 $\beta$ . Mosely, B.S.  
et al., Proc. Nat. Acad. Sci., 84, pp. 4572-4576  
(1987); Lonnemann, G. et al., Eur.J. Immunol., 19,  
10 pp. 1531-1536 (1989).

IL-1 $\beta$  is synthesized as a biologically  
inactive precursor, pIL-1 $\beta$ . pIL-1 $\beta$  lacks a  
conventional leader sequence and is not processed by a  
signal peptidase. March, C.J., Nature, 315,  
15 pp. 641-647 (1985). Instead, pIL-1 $\beta$  is cleaved by  
interleukin-1 $\beta$  converting enzyme ("ICE") between Asp-  
116 and Ala-117 to produce the biologically active  
C-terminal fragment found in human serum and synovial  
fluid. Sleath, P.R., et al., J. Biol. Chem., 265,  
20 pp. 14526-14528 (1992); A.D. Howard et al., J.  
Immunol., 147, pp. 2964-2969 (1991). Processing by ICE  
is also necessary for the transport of mature IL-1 $\beta$   
through the cell membrane.

ICE is a cysteine protease localized  
25 primarily in monocytes. It converts precursor IL-1 $\beta$  to  
the mature form. Black, R.A. et al., FEBS Lett., 247,  
pp. 386-390 (1989); Kostura, M.J. et al., Proc. Natl.  
Acad. Sci. USA, 86, pp. 5227-5231 (1989). ICE, or its  
homologues, also appears to be involved in the  
30 regulation of cell death or apoptosis. Yuan, J.  
et al., Cell, 75, pp. 641-652 (1993); Miura, M. et al.,  
Cell, 75, pp. 653-660 (1993); Nett-Fiordalisi, M.A.  
et al., J. Cell Biochem., 17B, p. 117 (1993). In  
particular, ICE or ICE homologues are thought to be  
35 associated with the regulation of apoptosis in

neurogenerative diseases, such as Alzheimer's and Parkinson's disease. Marx, J. and M. Baringa, Science, 259, pp. 760-762 (1993); Gagliardini, V. et al., Science, 263, pp. 826-828 (1994).

5 ICE has been previously described as a heterodimer composed of two subunits, p20 and p10 (20kDa and 10kDa molecular weight, respectively). These subunits are derived from a 45kDa proenzyme (p45) by way of a p30 form, through an activation mechanism  
10 that is autocatalytic. Thornberry, N.A. et al., Nature, 356, pp. 768-774 (1992). The ICE proenzyme has been divided into several functional domains: a prodomain (p14), a p22/20 subunit, a polypeptide linker and a p10 subunit. Thornberry et al., supra; Casano  
15 et al., Genomics, 20, pp. 474-481 (1994).

Full length p45 has been characterized by its cDNA and amino acid sequences. PCT patent applications WO 91/15577 and WO 94/00154. The p20 and p10 cDNA and amino acid sequences are also known. Thornberry  
20 et al., supra. Murine and rat ICE have also been sequenced and cloned. They have high amino acid and nucleic acid sequence homology to human ICE. Miller, D.K. et al., Ann. N.Y. Acad. Sci., 696, pp. 133-148 (1993); Molineaux, S.M. et al., Proc. Nat. Acad. Sci.,  
25 90, pp. 1809-1813 (1993). Knowledge of the primary structure of ICE, however, does not allow prediction of its tertiary structure. Nor does it afford an understanding of the structural, conformational and chemical interactions of ICE and its substrate pIL-1 $\beta$   
30 or other substrates or inhibitors.

ICE inhibitors represent a class of compounds useful for the control of inflammation or apoptosis or both. Peptide and peptidyl inhibitors of ICE have been described. PCT patent applications WO 91/15577; WO  
35 93/05071; WO 93/09135; WO 93/14777 and WO 93/16710; and

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of ICE, said backbone atom being selected from the group consisting of the carbonyl oxygen of Arg-341, the amide -NH- group of Arg-341, the carbonyl oxygen of Ser-339 and the amide -NH- group of Ser-339;

5                   b) a first and a second moderately hydrophobic moiety, said moieties each being capable of associating with a separate binding pocket of ICE when the inhibitor is bound thereto, said binding pocket being selected from the group consisting of the P2  
10 binding pocket, the P3 binding pocket, the P4 binding pocket and the P' binding pocket; and

                  c) an electronegative moiety comprising one or more electronegative atoms, said atoms being attached to the same atom or to adjacent  
15 atoms in the moiety and said moiety being capable of forming one or more hydrogen bonds or salt bridges with residues in the P1 binding pocket of ICE.

It is also an object of this invention to provide a method for identification, design or  
20 prediction of ICE inhibitors comprising the steps of:

                  a) selecting a candidate compound of defined chemical structure comprising at least two hydrogen bonding moieties, at least two moderately hydrophobic moieties and one electronegative moiety  
25 comprising one or more electronegative atoms attached either to the same atom or to adjacent atoms in the electronegative moiety;

                  b) determining a low-energy conformation for binding of said compound to the active site of ICE;

30                   c) evaluating the capability of said compound in said conformation to form at least two hydrogen bonds with the non-carbon backbone atoms of Arg-341 and Ser-339 of ICE;

                  d) evaluating the capability of said  
35 compound in said conformation to associate with at

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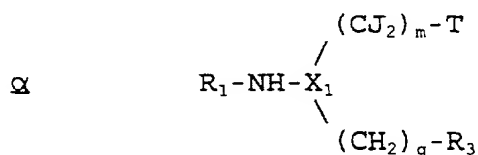
least two of the binding pockets of ICE selected from the group consisting of the P2 binding pocket, the P3 binding pocket, the P4 binding pocket and the P' binding pocket;

5 e) evaluating the capability of said compound in said conformation to interact with the P1 binding pocket of ICE; and

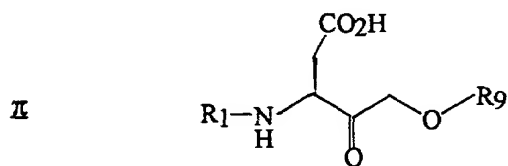
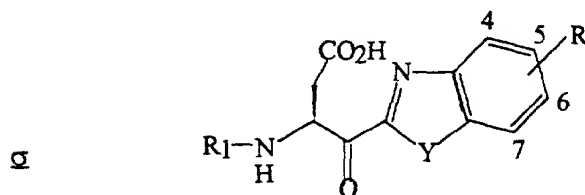
f) accepting or rejecting said candidate compound as an ICE inhibitor based on the  
10 determinations and evaluations carried out in the preceding steps.

It is a further object of this invention to provide novel classes of ICE inhibitors represented by formulas:

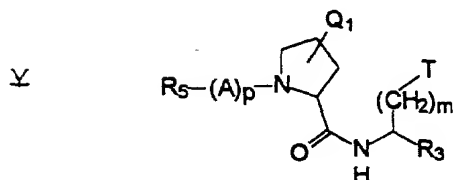
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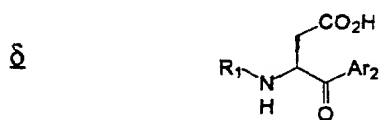


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ABBREVIATIONS AND DEFINITIONS

Abbreviations

	<u>Designation</u>	<u>Reagent or Fragment</u>
	Ala	alanine
5	Arg	arginine
	Asn	asparagine
	Asp	aspartic acid
	Cys	cysteine
	Gln	glutamine
10	Glu	glutamic acid
	Gly	glycine
	His	histidine
	Ile	isoleucine
	Leu	leucine
15	Lys	lysine
	Met	methionine
	Phe	phenylalanine
	Pro	proline
	Ser	serine
20	Thr	threonine
	Trp	tryptophan
	Tyr	tyrosine
	Val	valine.

Definitions

25           The following terms are employed herein:

          The term "active site" refers to any or all  
of the following sites in ICE: the substrate binding  
site, the site where an inhibitor binds and the site  
where the cleavage of substrate occurs. The active  
30 site is characterized by at least amino acid residues:  
173, 176, 177, 178, 179, 180, 236, 237, 238, 239, 244,  
248, 283, 284, 285, 290, 338, 339, 340, 341, 342, 343,

344, 345, 348, 352, 381, 383, using the sequence and numbering according to Thornberry et al., supra.

The terms "P binding pocket", "S subsite", "S pocket", and the like, refer to binding subsites, or portions of the substrate binding site on the ICE molecule. The amino acid residues of the substrate are given designations according to their position relative to the scissile bond, i.e. the bond which is broken by the protease. The residues are designated P1, P2, etc., for those extending toward the N-terminus of the substrate and P1', P2', etc., for those extending toward the C-terminus of the substrate. The portions of an inhibitor which correspond to the P or P' residues of the substrate are also labeled P1, P1', etc., by analogy with the substrate. The binding subsites of the ICE molecule which receive the residues labeled P1, P1', etc., are designated S1, S1', etc., or may alternately be designated "the P1 binding pocket", "the P1' binding pocket", etc. [I. Schechter and A. Berger, "On the Size of the Active Site in Proteases", Biochem. Biophys. Res. Commun., vol. 27, pp. 157-162 (1967).]

The terms "P2 binding pocket" or "S2 subsite" of the ICE active site are equivalent and are defined as the space surrounded by amino acid residues Pro-290, Val-338 or Trp-340.

The terms "P3 binding pocket" or "S3 subsite" of the ICE active site are equivalent and are defined as the space surrounded by amino acid residues Pro-177, Arg-178, Thr-180, Arg-341 or Pro-343.

The terms "P4 binding pocket" or "S4 subsite" of the ICE active site are equivalent and are defined as the space surrounded by amino acid residues His-342, Met-345, Val-348, Arg-352, Asp-381, Arg-383 or Trp-340.

The terms "P1 binding pocket" or "S1 subsite" of the ICE active site are equivalent and are defined as the space surrounded by amino acid residues Arg-179, His-237, Gln-283, or Arg-341.

5           The terms "P' binding pocket" or "S' subsite" of the ICE active site are equivalent and are defined as the space surrounded by amino acid residues Phe-173, Ile-176, His-237, Gly-238, Ile-239, Cys-244 or His-248.

10           The term "hydrophobic" refers to a moiety which tends not to dissolve in water and is fat-soluble. Hydrophobic moieties include, but are not limited to, hydrocarbons, such as alkanes, alkenes, alkynes, cycloalkanes, cycloalkenes, cycloalkynes and aromatic compounds, such as aryls, certain saturated  
15           and unsaturated heterocycles and moieties that are substantially similar to the side chains of hydrophobic natural and unnatural  $\alpha$ -amino acids, including valine, leucine, isoleucine, methionine, phenylalanine,  $\alpha$ -amino isobutyric acid, alloisoleucine, tyrosine, and  
20           tryptophan.

          The term "moderately hydrophobic" refers to a hydrophobic moiety in which one or two carbon atoms have been replaced with more polar atoms, such as oxygen or nitrogen.

25           The term "heterocycle" or "heterocyclic" refers to a stable mono- or polycyclic compound which may optionally contain one or two double bonds or may optionally contain one or more aromatic rings. Each heterocycle consists of carbon atoms and from one to  
30           four heteroatoms independently selected from a group including nitrogen, oxygen, and sulfur. As used herein, the terms "nitrogen heteroatoms" and "sulphur heteroatoms" include any oxidized form of nitrogen or sulfur and the quaternized form of any basic nitrogen.  
35           Heterocycles defined above include, for example,



those in the peptide chemistry arts when preparing synthetic analogues of naturally occurring peptides, including D and L forms. The naturally occurring amino acids are glycine, alanine, valine, leucine, iso-leucine, serine, methionine, threonine, phenylalanine, tyrosine, tryptophan, cysteine, proline, histidine, aspartic acid, asparagine, glutamic acid, glutamine,  $\gamma$ -carboxyglutamic acid, arginine, ornithine and lysine. Examples of "non-protein" alpha-amino acids include hydroxylysine, homoserine, homotyrosine, homophenylalanine, citrulline, kynurenine, 4-amino-phenylalanine, 3-(2-naphthyl)-alanine, 3-(1-naphthyl)-alanine, methionine sulfone, t-butyl-alanine, t-butylglycine, 4-hydroxyphenylglycine, aminoalanine, phenylglycine, vinylalanine, propargyl-glycine, 1,2,4-triazolo-3-alanine, 4,4,4-trifluoro-threonine, thyronine, 6-hydroxytryptophan, 5-hydroxytryptophan, 3-hydroxykynurenine, 3-aminotyrosine, trifluoromethyl-alanine, 2-thienylalanine, (2-(4-pyridyl)ethyl)-cysteine, 3,4-dimethoxy-phenylalanine, 3-(2-thiazolyl)-alanine, ibotenic acid, 1-amino-1-cyclopentane-carboxylic acid, 1-amino-1-cyclohexanecarboxylic acid, quisqualic acid, 3-trifluoromethylphenylalanine, 4-trifluoro-methylphenylalanine, cyclohexylalanine, cyclo-hexylglycine, thiohistidine, 3-methoxytyrosine, elastatinal, norleucine, norvaline, alloisoleucine, homoarginine, thioproline, dehydroproline, hydroxyproline, isonipectotic acid, homoproline, cyclohexylglycine,  $\alpha$ -amino-n-butyric acid, cyclohexylalanine, aminophenylbutyric acid, phenylalanines substituted at the ortho, meta, or para position of the phenyl moiety with one or two of the following: a (C<sub>1</sub>-C<sub>4</sub>) alkyl, a (C<sub>1</sub>-C<sub>4</sub>) alkoxy, halogen or nitro groups or substituted with a methylenedioxy group;  $\beta$ -2- and 3-thienyl-alanine,  $\beta$ -2- and 3-furanylalanine,  $\beta$ -2-, 3- and

4-pyridylalanine,  $\beta$ -(benzothienyl-2- and 3-yl)alanine,  $\beta$ -(1- and 2-naphthyl)alanine, O-alkylated derivatives of serine, threonine or tyrosine, S-alkylated cysteine, S-alkylated homocysteine, O-sulfate, O-phosphate and O-carboxylate esters of tyrosine, 3-sulfo-tyrosine, 3-carboxy-tyrosine, 3-phospho-tyrosine, 4-methane sulfonic acid ester of tyrosine, 4-methane phosphonic acid ester of tyrosine, 3,5-diiodotyrosine, 3-nitro-tyrosine,  $\epsilon$ -alkyl lysine, and delta-alkyl ornithine.

Any of these  $\alpha$ -amino acids may be substituted with a methyl group at the alpha position, a halogen at any aromatic residue on the  $\alpha$ -amino side chain, or an appropriate protective group at the O, N, or S atoms of the side chain residues. Appropriate protective groups are disclosed in "Protective Groups In Organic Synthesis," T.W. Greene and P.G.M. Wuts, J. Wiley & Sons, NY, NY, 1991.

The term " $\alpha$ -amino acid side chain residue" refers to a chemical moiety which is attached to the  $\alpha$ -carbon of an alpha-amino acid.

The term "bioisosteric replacement for  $-\text{CO}_2\text{H}$ " refers to group which may substitute for a carboxylic acid group in bioactive molecules. Examples of such groups are disclosed in Christopher A. Lipinski, "Bioisosteres in Drug Design" Annual Reports In Medical Chemistry, 21, pp. 286-88 (1986), and in C.W. Thornber, "Isosterism and Molecular Modification in Drug Design" Chemical Society Reviews, pp. 563-580 (1979).

The term "association" is used in reference to a condition of proximity between an inhibitor or portions thereof to an ICE molecule or portions thereof wherein the juxtaposition is energetically favored by electrostatic or van der Waals interactions.

The term "hydrogen bond" refers to a favorable interaction that occurs whenever a suitable



donor atom, X, bearing a proton, H, and a suitable acceptor atom, Y, have a separation of between 2.5Å and 3.5Å and where the angle X-H - - - Y is greater than 90 degrees. Suitable donor and acceptor atoms are well understood in medicinal chemistry (G.C. Pimentel and A.L. McClellan, The Hydrogen Bond, Freeman, San Francisco, 1960; R. Taylor and O. Kennard, "Hydrogen Bond Geometry in Organic Crystals", Accounts of Chemical Research, 17, pp. 320-326 (1984)).

The term "salt bridge" refers to the non-covalent attractive interaction between a positively charged moiety (P) and a negatively charged moiety (N) when the distance between the centers of mass of P and N is between 2 and 6 Angstroms. In calculating the center of mass, atoms which may contain a formal charge and atoms immediately adjacent to these are included. For example, a salt bridge may be formed between the positively charged guanidinium side chain of an arginine residue and the negative charged carboxylate side chain of a glutamate residue. Salt bridges are well understood in medicinal chemistry (L. Stryer, Biochemistry, Freeman, San Francisco, (1975); K.A. Dill, "Dominant Forces in Protein Folding", Biochemistry, 29, No. 31, pp. 7133-7155, (1990)).

The term "center of mass" refers to a point in three-dimensional space which represents a weighted average position of the masses that make up an object.

The terms "backbone chain" and "backbone" refer to the portion of a polypeptide which comprises the repeating unit -CO-CH-NH-.

The term "scaffold" refers to a structural building block which forms the basis of an ICE inhibitor according to this invention. Various moieties and functional groups are intended to be appended to the scaffold. The scaffolds of this

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invention are thus depicted having open valences.  
Various scaffolds of ICE inhibitors according to this  
invention include the portions:



or



15 In those scaffolds, the NH and CO or SO<sub>2</sub> moieties  
represent a first and a second hydrogen bonding moiety,  
said moieties each being capable of forming a hydrogen  
bond with a backbone atom of ICE, said backbone atom  
being selected from the group consisting of the  
20 carbonyl oxygen of Arg-341, the amide -NH- of Arg-341,  
the carbonyl oxygen of Ser-339 and the amide -NH- of  
Ser-339.

The term "substitute" refers to the  
replacement of a hydrogen atom in a compound with a  
25 substituent group. In the present invention, those  
hydrogen atoms which form a part of a hydrogen bonding  
moiety which is capable of forming a hydrogen bond with  
the carbonyl oxygen of Arg-341 of ICE or the carbonyl  
oxygen of Ser-339 of ICE are excluded from  
30 substitution. These excluded hydrogen atoms include  
those which comprise an -NH- group which is alpha to a  
Z or a -CO- group and are depicted as -NH- rather than  
an X group or some other designation in the following  
diagrams: (a) through (t), (v) through (y), and (I)  
35 through (VIID).

The term "straight chain" refers to a contiguous unbranching string of covalently bound members, i.e. atoms, which form a portion of a ring. The straight chain and the ring of which it forms a part may be substituted, but these substituents are not a part of the straight chain.

The term " $K_i$ " refers to a numerical measure of the effectiveness of a compound in inhibiting the activity of a target enzyme such as ICE. Lower values of  $K_i$  reflect higher effectiveness. The  $K_i$  value is a derived by fitting experimentally determined rate data to standard enzyme kinetic equations (see I. H. Segel, Enzyme Kinetics, Wiley-Interscience, 1975).

The term "minimize" refers to the systematic altering of the atomic geometry of a molecule or molecular complex so that any further minor perturbation of the atomic geometry would cause the total energy of the system as measured by a molecular mechanics force-field to increase. Minimization and molecular mechanics force-fields are well understood in computational chemistry [U. Burkert and N.L. Allinger, Molecular Mechanics, ACS Monograph 177, American Chemical Society, Washington, D.C. 1982 pages 59-78].

The term "strain energy" is used in this application to refer to the difference between the free conformation energy of a compound and the bound conformation energy of that compound when bound to ICE. The strain energy can be determined by the following steps: Evaluate the energy of the molecule when it has the conformation necessary for binding to ICE. Then minimize and reevaluate the energy -- this is the free conformation energy. The strain energy for binding of a potential inhibitor to ICE is the difference between the free conformation energy and the bound conformation energy. In a preferred embodiment, the strain energy

The term "patient" as used in this application refers to any mammal, especially humans.

10 lessening IL-1 mediated disease in a patient.

15 the pharmacological activity thereof.

or an anti-ICE active metabolite or residue thereof.

35 intermediates in obtaining the compounds of the

invention and their pharmaceutically acceptable acid addition salts. Salts derived from appropriate bases include alkali metal (e.g., sodium), alkaline earth metal (e.g., magnesium), ammonium and N-(C<sub>1-4</sub> alkyl)<sub>4</sub><sup>+</sup> salts.

This invention also envisions the "quaternization" of any basic nitrogen-containing groups of the compounds disclosed herein. The basic nitrogen can be quaternized with any agents known to those of ordinary skill in the art including, for example, lower alkyl halides, such as methyl, ethyl, propyl and butyl chloride, bromides and iodides; dialkyl sulfates including dimethyl, diethyl, dibutyl and diamyl sulfates; long chain halides such as decyl, lauryl, myristyl and stearyl chlorides, bromides and iodides; and aralkyl halides including benzyl and phenethyl bromides. Water or oil-soluble or dispersible products may be obtained by such quaternization.

The ICE inhibitors of this invention may contain one or more "asymmetric" carbon atoms and thus may occur as racemates and racemic mixtures, single enantiomers, diastereomeric mixtures and individual diastereomers. All such isomeric forms of these compounds are expressly included in the present invention. Each stereogenic carbon may be of the R or S configuration. Although specific compounds and scaffolds exemplified in this application may be depicted in a particular stereochemical configuration, compounds and scaffolds having either the opposite stereochemistry at any given chiral center or mixtures thereof are also envisioned.

The ICE inhibitors of this invention may comprise ring structures which may optionally be substituted at carbon, nitrogen or other atoms by

various substituents. Such ring structures may be singly or multiply substituted. Preferably, the ring structures contain between 0 and 3 substituents. When multiply substituted, each substituent may be picked independently of any other substituent as long as the combination of substituents results in the formation of a stable compound.

Combinations of substituents and variables envisioned by this invention are only those that result in the formation of stable compounds. The term "stable", as used herein, refers to compounds which possess stability sufficient to allow manufacture and administration to a mammal by methods known in the art. Typically, such compounds are stable at a temperature of 40°C or less, in the absence of moisture or other chemically reactive conditions, for at least a week.

#### DETAILED DESCRIPTION OF THE INVENTION

In order that the invention herein described may be more fully understood, the following detailed description is set forth.

We have discovered that compounds possessing the following novel combination of features are surprisingly effective ICE inhibitors:

a) a first and a second hydrogen bonding moiety, each of said moieties being capable of forming a hydrogen bond with a different backbone atom of ICE, said backbone atom being selected from the group consisting of the carbonyl oxygen of Arg-341, the amide -NH- group of Arg-341, the carbonyl oxygen of Ser-339 and the amide -NH- group of Ser-339;

b) a first and a second moderately hydrophobic moiety, said moieties each being capable of associating with a separate binding pocket of ICE when the inhibitor is bound thereto, said binding pocket

being selected from the group consisting of the P2 binding pocket, the P3 binding pocket, the P4 binding pocket and the P' binding pocket; and

5 c) an electronegative moiety comprising one or more electronegative atoms, said atoms being attached to the same atom or to adjacent atoms in the moiety and said moiety being capable of forming one or more hydrogen bonds or salt bridges with residues in the P1 binding pocket of ICE.

10 Preferably, any moderately hydrophobic moiety associating with the P2 binding pocket of ICE does so in such a way that:

15 a) the distance from the center of mass of the moderately hydrophobic moiety in the P2 binding pocket to the carbonyl oxygen of Arg-341 of ICE is between about 7.1Å and about 12.5Å;

20 b) the distance from the center of mass of the moderately hydrophobic moiety in the P2 binding pocket to the amide nitrogen of Arg-341 of ICE is between about 6.0Å and about 12Å; and

c) the distance from the center of mass of the moderately hydrophobic moiety in the P2 binding pocket to the carbonyl oxygen of Ser-339 of ICE is between about 3.7Å and about 9.5Å.

25 Preferably, any moderately hydrophobic moiety associating with the P3 binding pocket of ICE does so in such a way that:

30 a) the distance from the center of mass of the moderately hydrophobic moiety in the P3 binding pocket to the carbonyl oxygen of Arg-341 of ICE is between about 3.9Å and about 9.5Å;

35 b) the distance from the center of mass of the moderately hydrophobic moiety in the P3 binding pocket to the amide nitrogen of Arg-341 of ICE is between about 5.4Å and about 11Å; and

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5                    Preferably, any moderately hydrophobic moiety  
associating with the P4 binding pocket of ICE does so  
in such a way that:

b) the distance from the center of mass of the moderately hydrophobic moiety in the P4 binding pocket to the amide nitrogen of Arg-341 of ICE is between about 5.5Å and about 8.5Å; and

20                    Preferably, any moderately hydrophobic moiety  
associating with the P' binding pocket of ICE does so  
in such a way that:

b) the distance from the center of mass of the moderately hydrophobic moiety in the P' binding pocket to the amide nitrogen of Arg-341 of ICE is between about 10Å and about 15Å; and

c) the distance from the center of mass of the moderately hydrophobic moiety in the P' binding pocket to the carbonyl oxygen of Ser-339 of ICE is between about 8Å and about 12Å.



More preferably, all of the above associative conditions are met in the compounds of this invention.

The practitioner skilled in the art will appreciate that there are a number of means to design the inhibitors of the present invention. These same means may be used to select a candidate compound for screening as an ICE inhibitor. This design or selection may begin with selection of the various moieties which fill binding pockets.

There are a number of ways to select moieties to fill individual binding pockets. These include visual inspection of a physical model or computer model of the active site and manual docking of models of selected moieties into various binding pockets.

Modeling software that is well known and available in the art may be used. These include QUANTA [Molecular Simulations, Inc., Burlington, MA, 1992], SYBYL [Molecular Modeling Software, Tripos Associates, Inc., St. Louis, MO, 1992], AMBER [S.J. Weiner, P.A. Kollman, D.A. Case, U.C. Singh, C. Ghio, G. Alagona, and P. Weiner, J. Am. Chem. Soc., vol. 106, pp. 765-784 (1984)], or CHARMM [B.R. Brooks, R.E. Bruccoleri, B.D. Olafson, D.J. States, S Swaminathan, and M. Karplus, J. Comp. Chem. vol. 4, pp. 187-217 (1983)]. This

modelling step may be followed by energy minimization with standard molecular mechanics forcefields such as CHARMM and AMBER. In addition, there are a number of more specialized computer programs to assist in the process of selecting the binding moieties of this invention. These include:

1. GRID (Goodford, P.J. A Computational Procedure for Determining Energetically Favorable Binding Sites on Biologically Important Macromolecules. J. Med. Chem., 28, pp. 849-857 (1985)). GRID is available from Oxford University, Oxford, UK.

5 2. MCSS (Miranker, A.; Karplus, M. Functionality Maps of Binding Sites: A Multiple Copy Simultaneous Search Method. Proteins: Structure, Function and Genetics, 11, pp. 29-34 (1991)). MCSS is available from Molecular Simulations, Burlington, MA.

10 3. AUTODOCK (Goodsell, D.S.; Olsen, A.J. Automated Docking of Substrates to Proteins by Simulated Annealing. PROTEINS: Structure, Function and Genetics, 8, pp. 195-202 (1990)). AUTODOCK is available from the Scripps Research Institute, La Jolla, CA.

15 4. DOCK (Kuntz, I.D.; Blaney, J.M.; Oatley, S.J.; Langridge, R.; Ferrin, T.E. A Geometric Approach to Macromolecule-Ligand Interactions. J. Mol. Biol., 161, pp. 269-288 (1982)). DOCK is available from the University of California, San Francisco, CA.

20 Once suitable binding moieties have been selected, they can be assembled into a single inhibitor. This assembly may be accomplished by connecting the various moieties to a central scaffold. The assembly process may, for example, be done by visual inspection followed by manual model building,  
25 again using software such as Quanta or Sybyl. A number of other programs may also be used to help select ways to connect the various moieties. These include:

30 1. CAVEAT (Bartlett, P.A.; Shea, G.T.; Telfer, S.J.; Waterman, S. CAVEAT: A Program to Facilitate the Structure-Derived Design of Biologically Active Molecules. In "Molecular Recognition in Chemical and Biological Problems," Special Pub., Royal Chem. Soc., 78, pp. 182-196 (1989)). CAVEAT  
35 is available from the University of California, Berkeley, CA.

40 2. 3D Database systems such as MACCS-3D (MDL Information Systems, San Leandro, CA). This area has been recently reviewed by Martin (Martin, Y.C. 3D Database Searching in Drug Design. J. Med. Chem., 35, pp. 2145-2154 (1992)).

3. HOOK (available from Molecular Simulations, Burlington, MA).

In addition to the above computer assisted modeling of inhibitor compounds, the inhibitors of this invention may be constructed "de novo" using either an empty active site or optionally including some portions of a known inhibitor. Such methods are well known in the art. They include, for example:

1. LUDI (Bohm, H.J. The Computer Program LUDI: A New Method for the De Novo Design of Enzyme Inhibitors. J. Comp. Aid. Molec. Design., 6, 61-78 (1992)). LUDI is available from Biosym Technologies, San Diego, CA.

2. LEGEND (Nishibata, Y., Itai, A., Tetrahedron, 47, 8985 (1991)). LEGEND is available from Molecular Simulations, Burlington, MA.

3. LeapFrog (available from Tripos associates, St. Louis, MO).

A number of techniques commonly used for modeling drugs may be employed (For a review, see: Cohen, N.C.; Blaney, J.M.; Humblet, C.; Gund, P.; Barry, D.C., "Molecular Modeling Software and Methods for Medicinal Chemistry", J. Med. Chem., 33, pp. 883-894 (1990)). There are likewise a number of examples in the chemical literature of techniques that can be applied to specific drug design projects. For a review, see: Navia, M.A. and Murcko, M.A., "The Use of Structural Information in Drug Design", Current Opinions in Structural Biology, 2, pp. 202-210 (1992). Some examples of these specific applications include: Baldwin, J.J. et al., "Thienothiopyran-2-sulfonamides: Novel Topically Active Carbonic Anhydrase Inhibitors for the Treatment of Glaucoma", J. Med. Chem., 32, pp. 2510-2513 (1989); Appelt, K. et al., "Design of Enzyme Inhibitors Using Iterative Protein Crystallographic Analysis", J. Med. Chem., 34, pp. 1925-1934 (1991); and

Ealick, S.E. et al., "Application of Crystallographic and Modeling Methods in the Design of Purine Nucleotide Phosphorylase Inhibitors" Proc. Nat. Acad. Sci. USA, 88, pp. 11540-11544 (1991).

5                   Using the novel combination of steps of the  
present invention, the skilled artisan can  
advantageously avoid time consuming and expensive  
experimentation to determine enzymatic inhibition  
activity of particular compounds. The method also is  
10           useful to facilitate rational design of ICE inhibitors  
and therapeutic and prophylactic agents against  
IL-1-mediated diseases. Accordingly, the present  
invention relates to such inhibitors.

A variety of conventional techniques may be used to carry out each of the above evaluations as well as the evaluations necessary in screening a candidate compound for ICE inhibiting activity. Generally, these techniques involve determining the location and binding proximity of a given moiety, the occupied space of a bound inhibitor, the deformation energy of binding of a given compound and electrostatic interaction energies. Examples of conventional techniques useful in the above evaluations include: quantum mechanics, molecular mechanics, molecular dynamics, Monte Carlo sampling, systematic searches and distance geometry methods (G.R. Marshall, Ann. Ref. Pharmacol. Toxicol., 27, p. 193 (1987)). Specific computer software has been developed for use in carrying out these methods. Examples of programs designed for such uses include: Gaussian 92, revision E.2 (M.J. Frisch, Gaussian, Inc., Pittsburgh, PA ©1993); AMBER, version 4.0 (P.A. Kollman, University of California at San Francisco, ©1993); QUANTA/CHARMM [Molecular Simulations, Inc., Burlington, MA ©1992]; and Insight II/Discover (Biosysm Technologies Inc., San Diego, CA ©1992). These programs may be implemented,

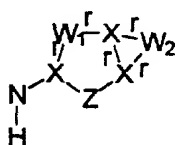
for instance, using a Silicon Graphics Indigo 2 workstation or IBM RISC/6000 workstation model 550. Other hardware systems and software packages will be known and of evident applicability to those skilled in the art.

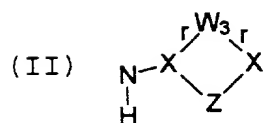
Different classes of active ICE inhibitors, according to this invention, may interact in similar ways with the various binding pockets of the ICE active site. The spatial arrangement of these important groups is often referred to as a pharmacophore. The concept of the pharmacophore has been well described in the literature (D. Mayer, C.B. Naylor, I. Motoc, and G.R. Marshall, J. Comp. Aided Molec. Design vol. 1, pp. 3-16 (1987); A. Hopfinger and B.J. Burke, in Concepts and Applications of Molecular Similarity, M.A. Johnson and G.M. Maggiora, ed., Wiley (1990)).

Different classes of ICE inhibitors of this invention may also use different scaffolds or core structures, but all of these cores will allow the necessary moieties to be placed in the active site such that the specific interactions necessary for binding may be obtained. These compounds are best defined in terms of their ability to match the pharmacophore, i.e., their structural identity relative to the shape and properties of the active site of ICE.

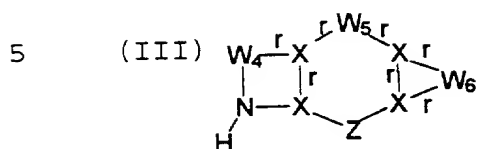
The ICE inhibitors of one embodiment of this invention comprise a first and a second hydrogen bonding moiety, a first and a second moderately hydrophobic moiety, and an electronegative moiety which comprise or are covalently bound to one of the following scaffolds:

(I)

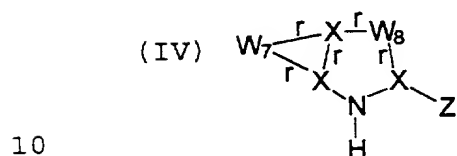




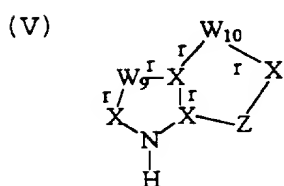
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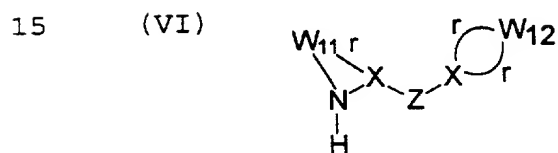
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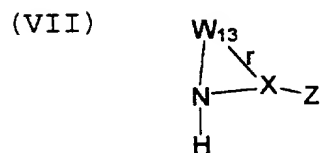
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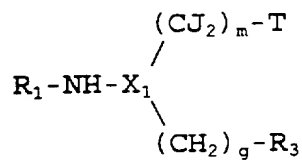


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The ICE inhibitors of another embodiment (A) of this invention are those of formula  $\alpha$ :

25

$\alpha$



,

wherein:

$X_1$  is CH or N;

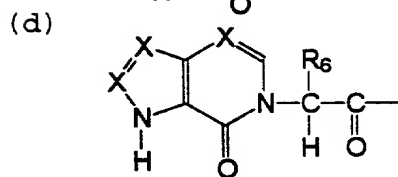
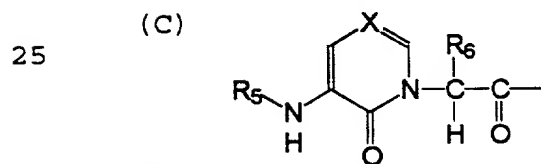
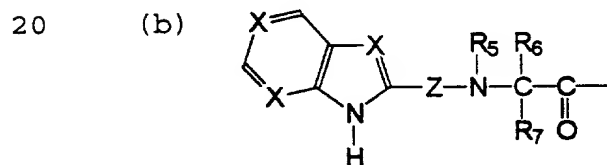
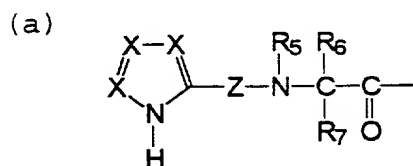
$g$  is 0 or 1;

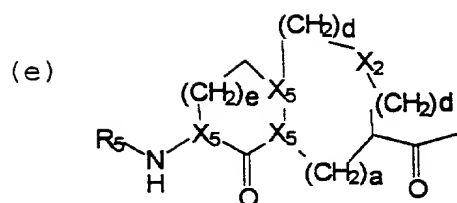
each J is independently selected from the group  
5 consisting of -H, -OH, and -F, provided that when a  
first and second J are bound to a C and said first J is  
-OH, said second J is -H;

$m$  is 0, 1, or 2;

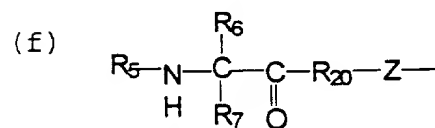
10 T is  $-Ar_3$ , -OH,  $-CF_3$ ,  $-CO-CO_2H$ ,  $-CO_2H$  or any  
bioisosteric replacement for  $-CO_2H$ ;

$R_1$  is selected from the group consisting of the  
following formulae, in which any ring may optionally be  
singly or multiply substituted at any carbon by  $Q_1$ , at  
any nitrogen by  $R_5$ , or at any atom by =O, -OH,  $-CO_2H$ , or  
15 halogen, and in which any saturated ring may optionally  
be unsaturated at one or two bonds:



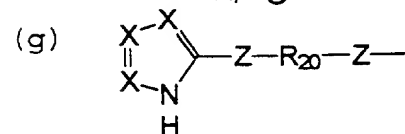


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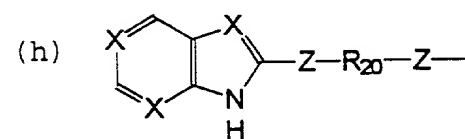


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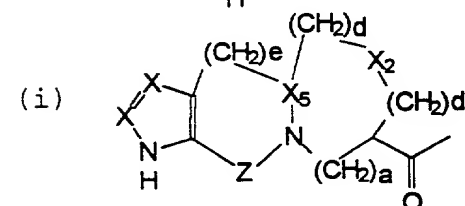


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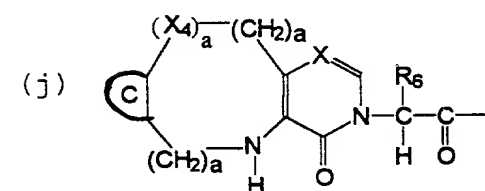
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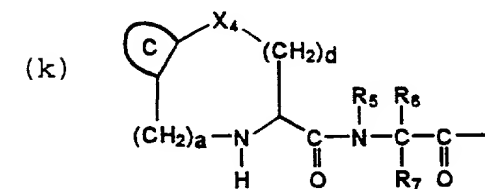


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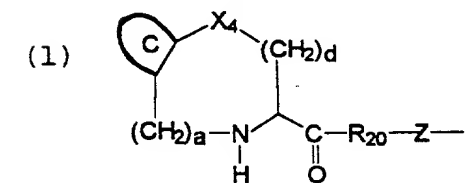


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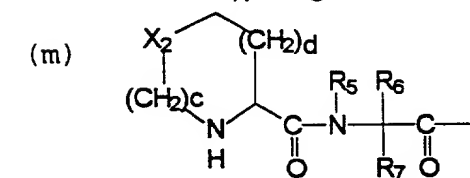
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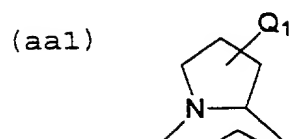
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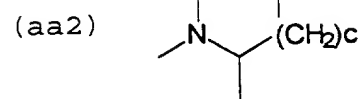
*i*

;

R<sub>20</sub> is selected from the group consisting of:

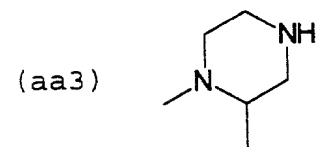


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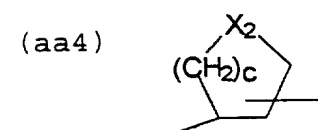


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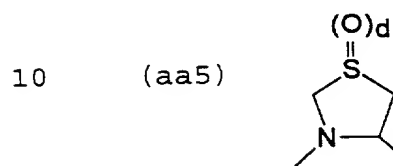
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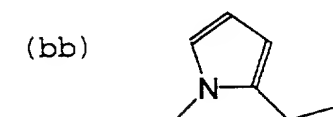
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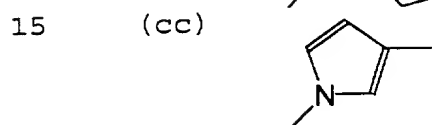
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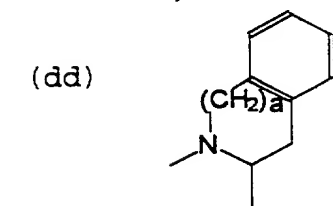
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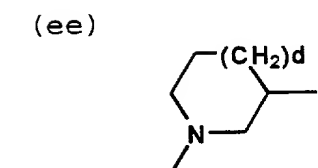
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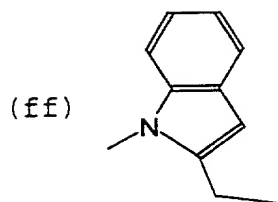
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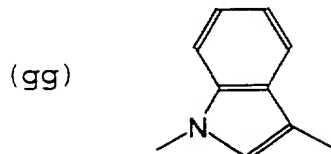
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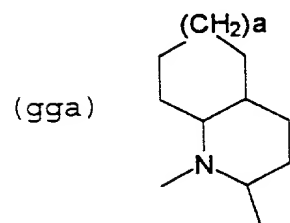
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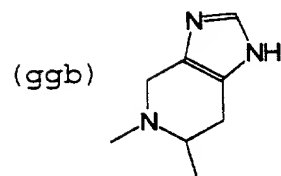
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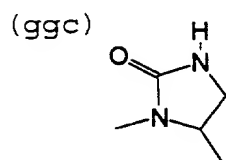
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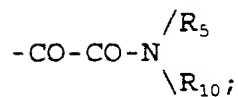


;

wherein each ring C is independently chosen from the group consisting of benzo, pyrido, thieno, pyrrolo, furano, thiazolo, isothiazolo, oxazolo, isoxazolo, pyrimido, imidazolo, cyclopentyl, and cyclohexyl;

$R_3$  is

- CN,
- CH=CH- $R_9$ ,
- CH=N-O- $R_9$ ,
- ( $CH_2$ )<sub>1-3</sub>- $T_1$ - $R_9$ ,
- CJ<sub>2</sub>- $R_9$ ,
- CO- $R_{13}$ , or



each  $R_4$  is independently selected from the group  
5 consisting of:

- H,
- Ar<sub>1</sub>,
- R<sub>9</sub>,
- T<sub>1</sub>-R<sub>9</sub>, and
- 10 - (CH<sub>2</sub>)<sub>1,2,3</sub>-T<sub>1</sub>-R<sub>9</sub>,

each  $T_1$  is independently selected from the group  
consisting of:

- CH=CH-,
- O-,
- 15 -S-,
- SO-,
- SO<sub>2</sub>-,
- NR<sub>10</sub>-,
- NR<sub>10</sub>-CO-,
- 20 -CO-,
- O-CO-,
- CO-O-,
- CO-NR<sub>10</sub>-,
- O-CO-NR<sub>10</sub>-,
- 25 -NR<sub>10</sub>-CO-O-,
- NR<sub>10</sub>-CO-NR<sub>10</sub>-,
- SO<sub>2</sub>-NR<sub>10</sub>-,
- NR<sub>10</sub>-SO<sub>2</sub>-, and
- NR<sub>10</sub>-SO<sub>2</sub>-NR<sub>10</sub>-,

30 each  $R_5$  is independently selected from the group  
consisting of:

- H,
- Ar<sub>1</sub>,

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$$-\text{CO}-\text{O}-\text{R}_9,$$
$$/\text{Ar}_1$$

/Ar,

$$/R_9$$
$$/R_9$$

20

$R_7$  is  $-H$  and  $R_6$  is

25

-R<sub>9</sub>, or

$$-(\text{CH}_2)_{1,2,3}-\text{T}_1-\text{R}_9;$$

30

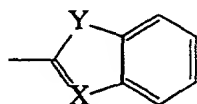
each  $R_{10}$  is independently selected from the group consisting of -H or a  $C_{1-6}$  straight or branched alkyl group;

each  $R_{13}$  is independently selected from the group consisting of  $-Ar_2$  and  $-R_4$ ;

each  $Ar_1$  is a cyclic group independently selected from the set consisting of an aryl group which contains 6, 10, 12, or 14 carbon atoms and between 1 and 3 rings, a cycloalkyl group which contains between 3 and 15 carbon atoms and between 1 and 3 rings, said cycloalkyl group being optionally benzofused, and a heterocycle group containing between 5 and 15 ring atoms and between 1 and 3 rings, said heterocycle group containing at least one heteroatom group selected from  $-O-$ ,  $-S-$ ,  $-SO-$ ,  $-SO_2-$ ,  $=N-$ , and  $-NH-$ , said heterocycle group optionally containing one or more double bonds, said heterocycle group optionally comprising one or more aromatic rings, and said cyclic group optionally being singly or multiply substituted by  $=O$ ,  $-OH$ , perfluoro  $C_{1-3}$  alkyl, or  $-Q_1$ ;

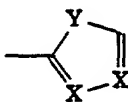
each  $Ar_2$  is independently selected from the following group, in which any ring may optionally be substituted by  $-Q_1$ :

(hh)



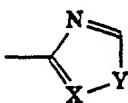
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(ii)



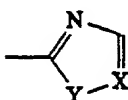
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(jj)



; and

(kk)



;

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Ar<sub>3</sub> is a cyclic group selected from the set consisting of a phenyl ring, a 5-membered heteroaromatic ring, and a 6-membered heteroaromatic ring, said heteroaromatic rings comprising 1-3 heteroatom groups selected from -O-, -S-, -SO-, -SO<sub>2</sub>-, =N-, and -NH-, said cyclic group optionally being singly or multiply substituted with =O, -OH, halogen, perfluoro C<sub>1-3</sub> alkyl, or -CO<sub>2</sub>H;

each Q<sub>1</sub> is independently selected from the group consisting of:

-Ar<sub>1</sub>  
-R<sub>9</sub>,  
-T<sub>1</sub>-R<sub>9</sub>, and  
-(CH<sub>2</sub>)<sub>1,2,3</sub>-T<sub>1</sub>-R<sub>9</sub>,

provided that when -Ar<sub>1</sub> is substituted with a Q<sub>1</sub> group which comprises one or more additional -Ar<sub>1</sub> groups, said additional -Ar<sub>1</sub> groups are not substituted with Q<sub>1</sub>;

each X is independently selected from the group consisting of =N-, and =CH-;

each X<sub>2</sub> is independently selected from the group consisting of -O-, -CH<sub>2</sub>-, -NH-, -S-, -SO-, and -SO<sub>2</sub>;  
each X<sub>3</sub> is independently selected from the group consisting of -CH<sub>2</sub>-, -S-, -SO-, and -SO<sub>2</sub>-;

each X<sub>4</sub> is independently selected from the group consisting of -CH<sub>2</sub>- and -NH-;

each X<sub>5</sub> is independently selected from the group consisting of -CH- and -N-;

| |

$X_6$  is CH or N, provided that when  $X_6$  is N in the  $R_1$  group labeled (o) and  $X_5$  is CH and  $X_2$  is  $CH_2$  the ring of the  $R_1$  group labeled (o) must be substituted by  $Q_1$  or benzofused;

5 each Y is independently selected from the group consisting of -O- and -S-;

each Z is independently CO or  $SO_2$ ,

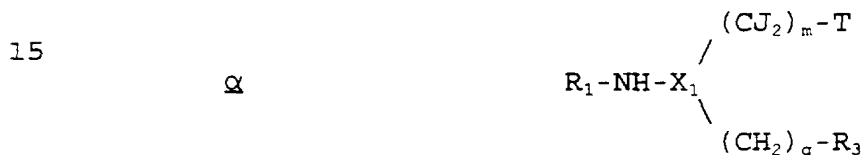
each a is independently 0 or 1,

each c is independently 1 or 2,

10 each d is independently 0, 1, or 2, and

each e is independently 0, 1, 2, or 3.

The ICE inhibitors of another embodiment (B) of this invention are those of formula  $\alpha$ :



20 wherein:

$X_1$  is -CH;

g is 0 or 1;

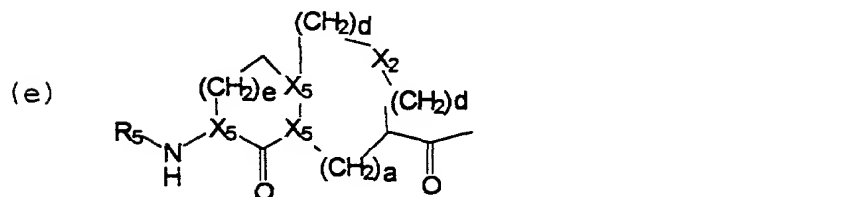
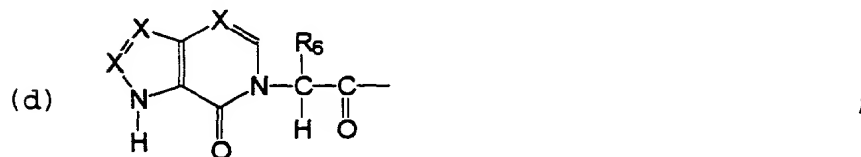
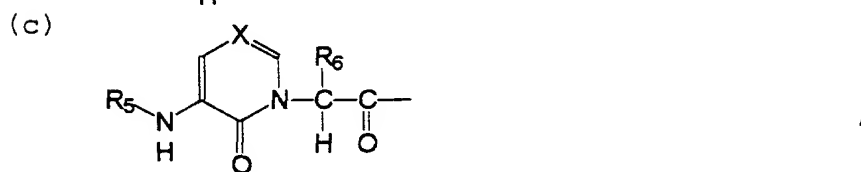
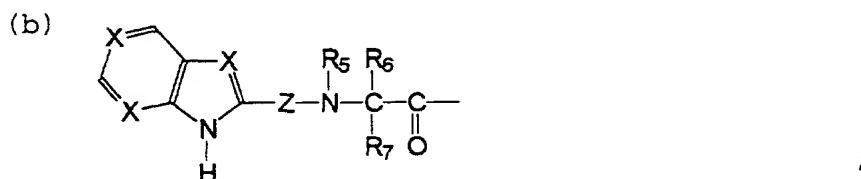
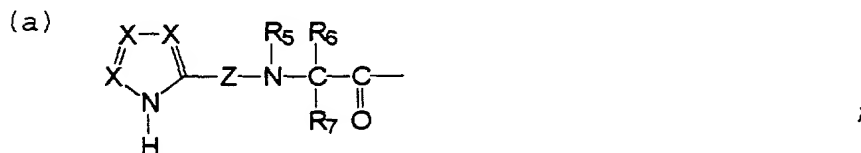
25 each J is independently selected from the group consisting of -H, -OH, and -F, provided that when a first and second J are bound to a C and said first J is -OH, said second J is -H;



m is 0, 1, or 2;

T is -OH, -CO-CO<sub>2</sub>H, -CO<sub>2</sub>H or any bioisosteric replacement for -CO<sub>2</sub>H;

R<sub>1</sub> is selected from the group consisting of the following formulae, in which any ring may optionally be singly or multiply substituted at any carbon by Q<sub>1</sub>, at any nitrogen by R<sub>5</sub>, or at any atom by =O, -OH, -CO<sub>2</sub>H, or halogen, any saturated ring may optionally be unsaturated at one or two bonds; and wherein R<sub>1</sub> (e) and R<sub>1</sub> (y) are optionally benzofused;

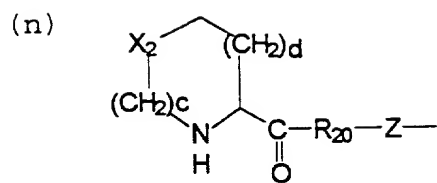


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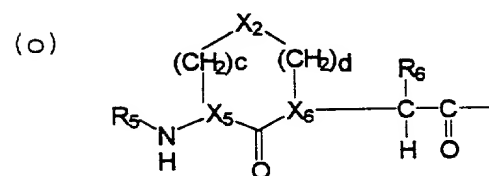
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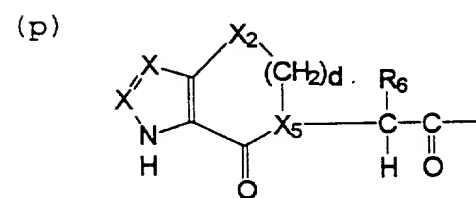


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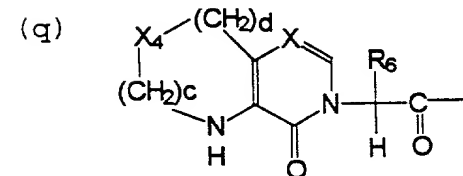
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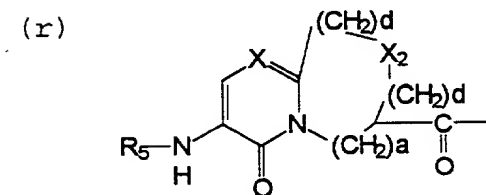


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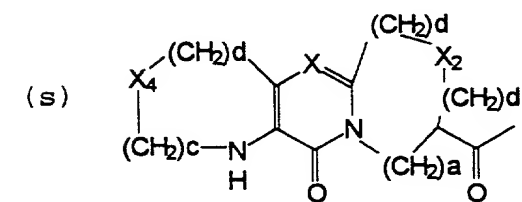


;



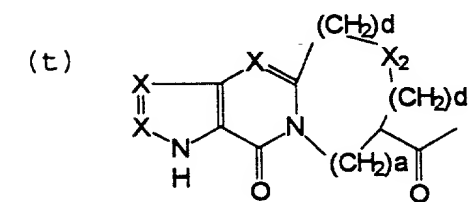
;

15

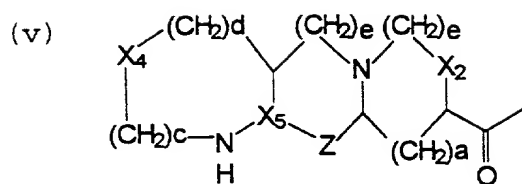


;

20

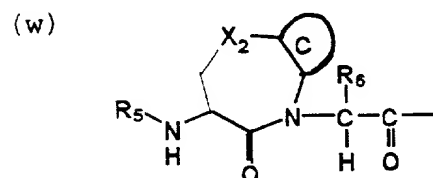


;

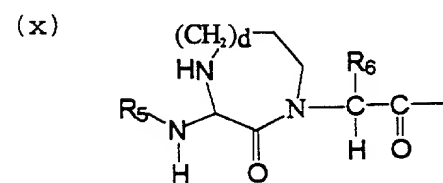


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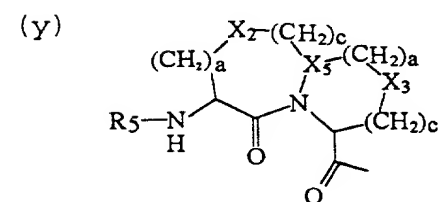
5



;



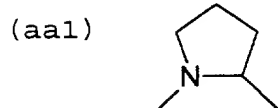
;



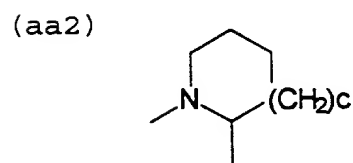
;

10

$R_{20}$  is selected from the group consisting of:

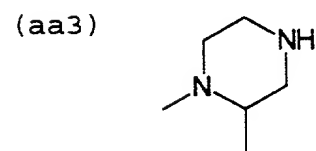


;



;

15



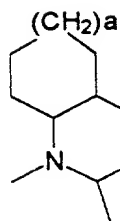
;

20

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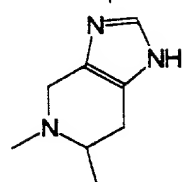


(gga)



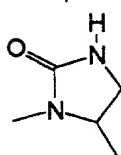
;

(ggb)



; and

(ggc)



;

wherein each ring C is independently chosen from the group consisting of benzo, pyrido, thieno, pyrrolo, furano, thiazolo, isothiazolo, oxazolo, isoxazolo, pyrimido, imidazolo, cyclopentyl, and cyclohexyl;

R<sub>3</sub> is

-CN,

-CH=CH-R<sub>9</sub>,

-CH=N-O-R<sub>9</sub>,

-(CH<sub>2</sub>)<sub>1-3</sub>-T<sub>1</sub>-R<sub>9</sub>,

-CJ<sub>2</sub>-R<sub>9</sub>,

-CO-R<sub>13</sub>, or

-CO-CO-N /R<sub>5</sub>

\R<sub>10</sub>;

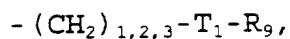
each R<sub>4</sub> is independently selected from the group consisting of:

-H,

-Ar<sub>1</sub>,

-R<sub>9</sub>,

-T<sub>1</sub>-R<sub>9</sub>, and

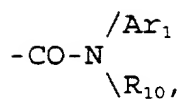


each  $\text{T}_1$  is independently selected from the group consisting of:

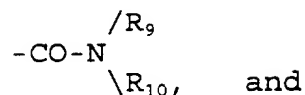
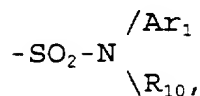
- CH=CH-,
- 5        -O-,
- S-,
- SO-,
- SO<sub>2</sub>-,
- NR<sub>10</sub>-,
- 10       -NR<sub>10</sub>-CO-,
- CO-,
- O-CO-,
- CO-O-,
- CO-NR<sub>10</sub>-,
- 15       -O-CO-NR<sub>10</sub>-,
- NR<sub>10</sub>-CO-O-,
- NR<sub>10</sub>-CO-NR<sub>10</sub>-,
- SO<sub>2</sub>-NR<sub>10</sub>-,
- NR<sub>10</sub>-SO<sub>2</sub>-,        and
- 20       -NR<sub>10</sub>-SO<sub>2</sub>-NR<sub>10</sub>-,

each  $\text{R}_5$  is independently selected from the group consisting of:

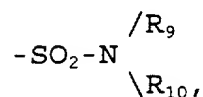
- H,
- Ar<sub>1</sub>,
- 25       -CO-Ar<sub>1</sub>,
- SO<sub>2</sub>-Ar<sub>1</sub>,
- CO-NH<sub>2</sub>,
- SO<sub>2</sub>-NH<sub>2</sub>,
- R<sub>9</sub>,
- 30       -CO-R<sub>9</sub>,
- CO-O-R<sub>9</sub>,
- SO<sub>2</sub>-R<sub>9</sub>,



5



10



R<sub>6</sub> and R<sub>7</sub> taken together form a saturated 4-8 member carbocyclic ring or heterocyclic ring containing -O-, -S-, or -NH-; or

15

R<sub>7</sub> is -H and R<sub>6</sub> is:

-H,

-Ar<sub>1</sub>,

-R<sub>9</sub>,

20

-(CH<sub>2</sub>)<sub>1,2,3</sub>-T<sub>1</sub>-R<sub>9</sub>, or

an α-amino acid side chain residue;

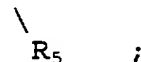
each R<sub>9</sub> is a C<sub>1-6</sub> straight or branched alkyl group optionally singly or multiply substituted by -OH, -F, or =O and optionally substituted with one or two Ar<sub>1</sub> groups;

25

each R<sub>10</sub> is independently selected from the group consisting of -H or a C<sub>1-6</sub> straight or branched alkyl group;

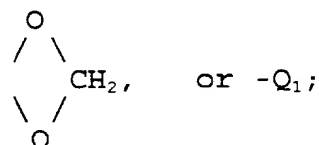
each R<sub>13</sub> is independently selected from the group consisting of -Ar<sub>2</sub>, -R<sub>4</sub> and -N-OH

30



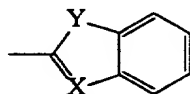


each Ar<sub>1</sub> is a cyclic group independently selected from the set consisting of an aryl group which contains 6, 10, 12, or 14 carbon atoms and between 1 and 3 rings, a cycloalkyl group which contains between 3 and 15 carbon atoms and between 1 and 3 rings, said cycloalkyl group being optionally benzofused, and a heterocycle group containing between 5 and 15 ring atoms and between 1 and 3 rings, said heterocycle group containing at least one heteroatom group selected from -O-, -S-, -SO-, -SO<sub>2</sub>-, =N-, and -NH-, said heterocycle group optionally containing one or more double bonds, said heterocycle group optionally comprising one or more aromatic rings, and said cyclic group optionally being singly or multiply substituted by -NH<sub>2</sub>, -CO<sub>2</sub>H, -Cl, -F, -Br, -I, -NO<sub>2</sub>, -CN, =O, -OH, -perfluoro C<sub>1-3</sub> alkyl,



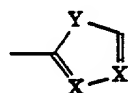
each Ar<sub>2</sub> is independently selected from the following group, in which any ring may optionally be singly or multiply substituted by -Q<sub>1</sub> and -Q<sub>2</sub>:

(hh)



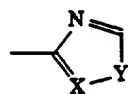
,

(ii)



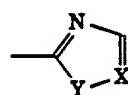
,

(jj)



, and

(kk)



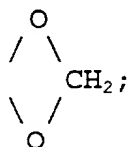
;

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each  $Q_1$  is independently selected from the group consisting of

- 5            $-Ar_1$   
               $-O-Ar_1$   
               $-R_9$ ,  
               $-T_1-R_9$ ,                                 and  
               $-(CH_2)_{1,2,3}-T_1-R_9$ ;

each  $Q_2$  is independently selected from the group consisting of  $-OH$ ,  $-NH_2$ ,  $-CO_2H$ ,  $-Cl$ ,  $-F$ ,  $-Br$ ,  $-I$ ,  
 10            $-NO_2$ ,  $-CN$ ,  $-CF_3$ , and



15           provided that when  $-Ar_1$  is substituted with a  $Q_1$  group which comprises one or more additional  $-Ar_1$  groups, said additional  $-Ar_1$  groups are not substituted with  $Q_1$ ;

20           each  $X$  is independently selected from the group consisting of  $=N-$ , and  $=CH-$ ;

             each  $X_2$  is independently selected from the group consisting of  $-O-$ ,  $-CH_2-$ ,  $-NH-$ ,  $-S-$ ,  $-SO-$ , and  $-SO_2-$ ;

             each  $X_3$  is independently selected from the group consisting of  $-CH_2-$ ,  $-S-$ ,  $-SO-$ , and  $-SO_2-$ ;

25           each  $X_4$  is independently selected from the group consisting of  $-CH_2-$  and  $-NH-$ ;

             each  $X_5$  is independently selected from the group consisting of  $-CH-$  and  $-N-$ ;  
                                   |                                 |

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5        each Y is independently selected from the group  
consisting of -O- and -S-, and -NH;

each  $a$  is independently 0 or 1,

10           each  $d$  is independently 0, 1, or 2, and

provided that when

15                    R<sub>6</sub> is an  $\alpha$ -amino acid side chain residue, and  
                     R<sub>7</sub> is -H,  
                     then (aa1) and (aa2) must be substituted with Q<sub>1</sub>;

$R_1$  is (o),

20 J is -H,

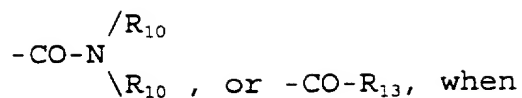
m is 1,

$R_7$  is  $-H$ ,

25                      X<sub>5</sub> is -CH- ,

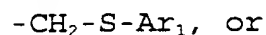
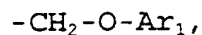
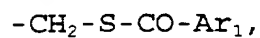
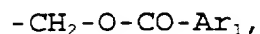
$$X_6 \text{ is } -N-, \text{ and}$$

R<sub>3</sub> is

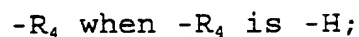


5

R<sub>13</sub> is:



10



then the ring of the R<sub>1</sub>(o) group must be substituted with Q<sub>1</sub> or benzofused; and

provided that when

15

R<sub>1</sub> is (w),

g is 0,

J is -H,

m is 1,

T is -CO<sub>2</sub>H or -CO-NH-OH,

X<sub>2</sub> is O,

20

R<sub>5</sub> is benzyloxycarbonyl, and

ring C is benzo,

then R<sub>3</sub> cannot be -CO-R<sub>13</sub> when:

R<sub>13</sub> is -CH<sub>2</sub>-O-Ar<sub>1</sub> and

25

Ar<sub>1</sub> is 1-phenyl-3-chloro- or  
3-trifluoromethyl-pyrazole-5-yl;

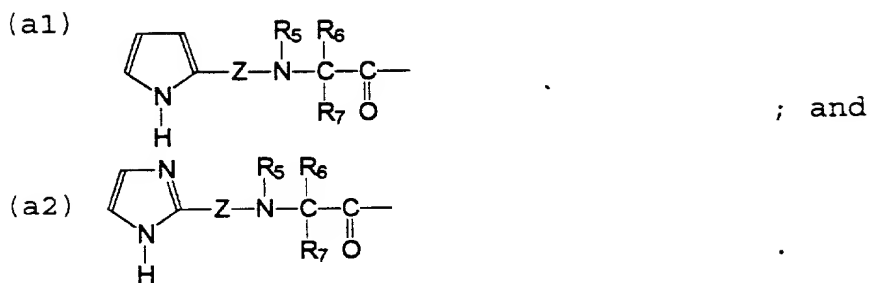
or when

R<sub>13</sub> is -CH<sub>2</sub>-O-CO-Ar<sub>1</sub> and

Ar<sub>1</sub> is 2,6-dichlorophenyl.

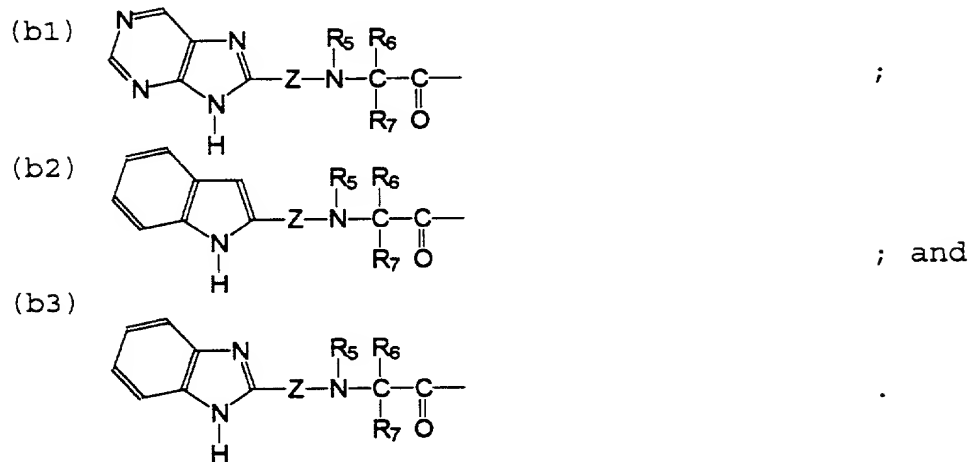
30

Preferred forms of the R<sub>1</sub> group (a) for  
embodiments A and B are:



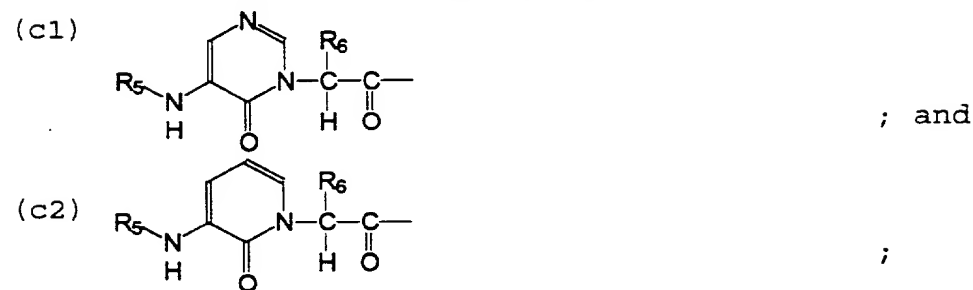
5

Preferred forms of the R<sub>1</sub> group (b) are:



10

Preferred forms of the R<sub>1</sub> group (c) are:



15

provided that when R<sub>1</sub> is (c1),

20

g is 0,

J is -H,

m is 1,

T is -CO<sub>2</sub>H,

X is N,

25

R<sub>5</sub> is benzyloxycarbonyl, and

R<sub>6</sub> is -H,

then  $R_3$  cannot be  $-\text{CO}-R_{13}$  when

$R_{13}$  is  $-\text{CH}_2-\text{O}-\text{Ar}_1$  and

$\text{Ar}_1$  is a chloro-substituted 1-phenyl-3-trifluoromethyl-pyrazole-5-yl, or when

5

$R_{13}$  is  $-\text{CH}_2-\text{O}-\text{CO}-\text{Ar}_1$  and

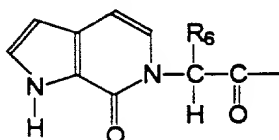
$\text{Ar}_1$  is 2,6-dichlorophenyl,

and when the 2-position of the scaffold ring is substituted with para-fluoro-phenyl;

10

Preferred forms of the  $R_1$  group (d) are:

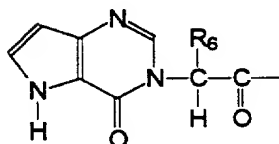
(d1)



;

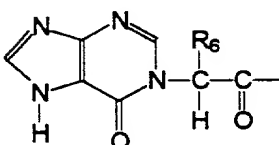
15

(d2)



;

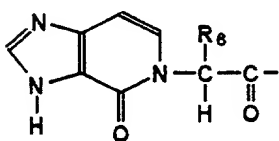
(d3)



; and

20

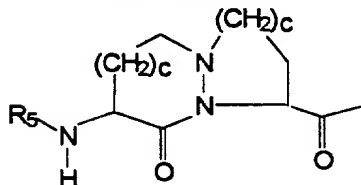
(d4)



.

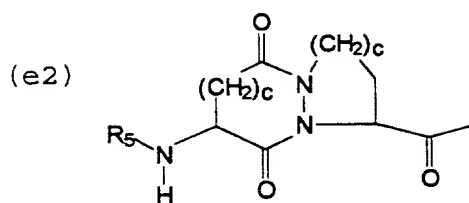
Preferred forms of the  $R_1$  group (e) are:

(e1)

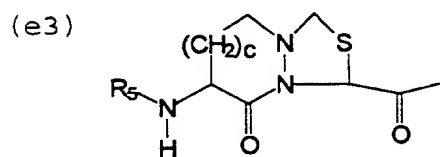


;

25

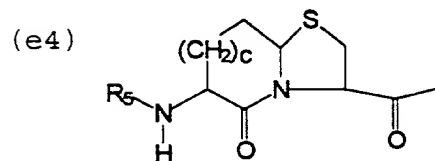


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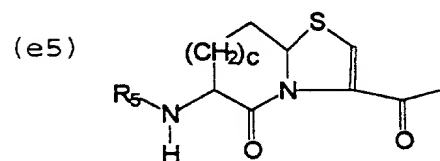


5

;

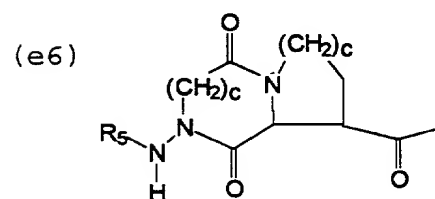


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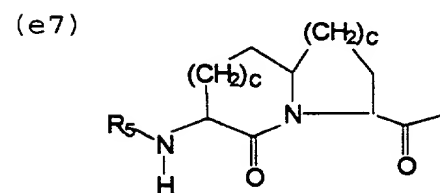


10

;

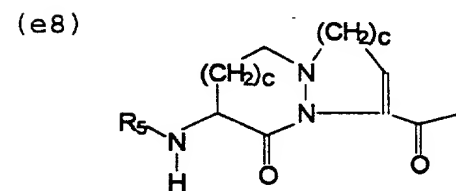


;



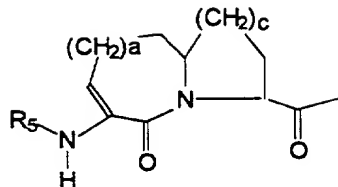
15

which is optionally benzofused;



; and

(e9)



provided that when  $R_1$  is (e4),

5

$g$  is 0,

$J$  is -H,

$m$  is 1,

$T$  is  $-\text{CO}_2\text{H}$ ,

$R_5$  is benzyloxycarbonyl, and

10

$c$  is 1,

then  $R_3$  cannot be  $-\text{CO}-R_{13}$  when

$R_{13}$  is  $-\text{CH}_2-\text{O}-\text{Ar}_1$  and

$\text{Ar}_1$  is 1-phenyl-3-trifluoromethyl-pyrazole-5-yl, wherein the phenyl is optionally substituted with a chlorine atom; or when

15

$R_{13}$  is  $-\text{CH}_2-\text{O}-\text{CO}-\text{Ar}_1$  and

$\text{Ar}_1$  is 2,6-dichlorophenyl,

and when the 2-position of the scaffold ring is substituted with para-fluoro-phenyl; and

20

also provided that when

$R_1$  is (e7),

$g$  is 0,

$J$  is -H,

$m$  is 1,

25

$T$  is  $-\text{CO}_2\text{H}$  or  $-\text{CO}-\text{NH}-\text{OH}$ ,

$R_5$  is a protective group for the N atom of an amino acid side chain residue, and

each  $c$  is 1,

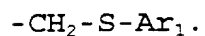
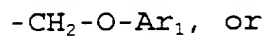
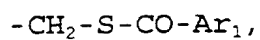
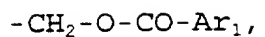
then  $R_3$  cannot be  $-\text{CO}-R_{13}$  when

30

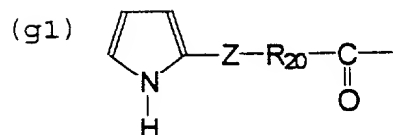
$R_{13}$  is:

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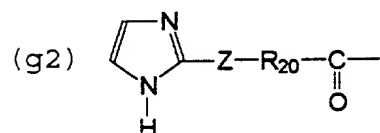




5 Preferred forms of the  $R_1$  group (g) are:

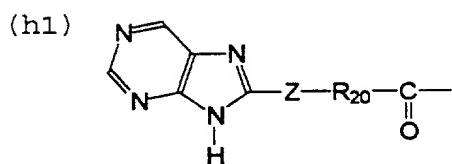


; and



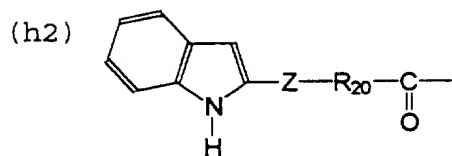
10

Preferred forms of the  $R_1$  group (h) are:

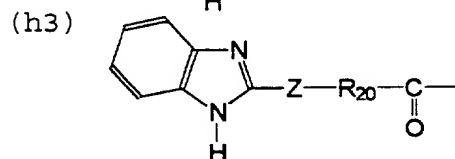


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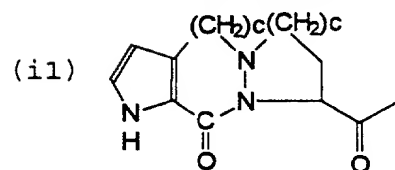
i



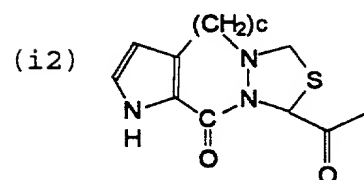
; and



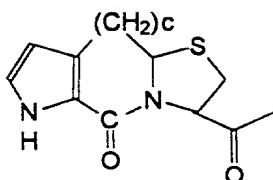
20 Preferred forms of the  $R_1$  group (i) are:



2

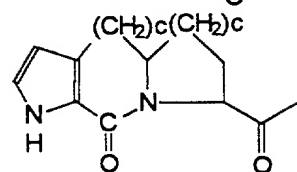


(i3)



; and

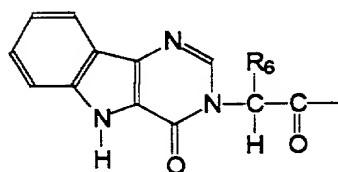
(i4)



5

Preferred forms of the R<sub>1</sub> group (j) are:

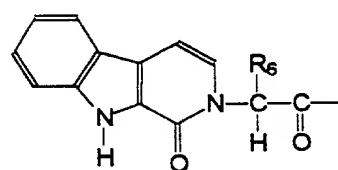
(j1)



;

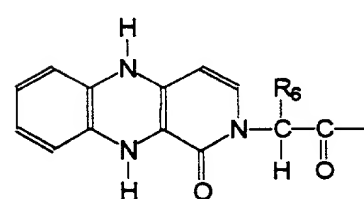
10

(j2)



;

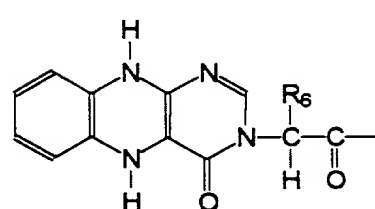
(j3)



; and

15

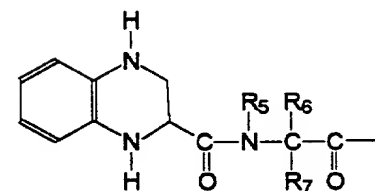
(j4)



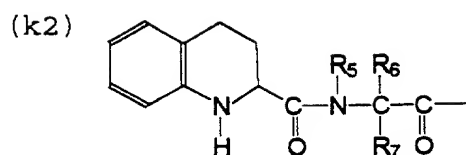
Preferred forms of the R<sub>1</sub> group (k) are:

20

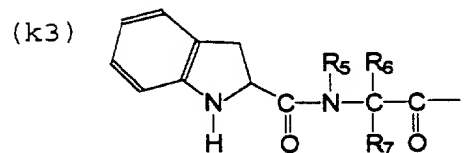
(k1)



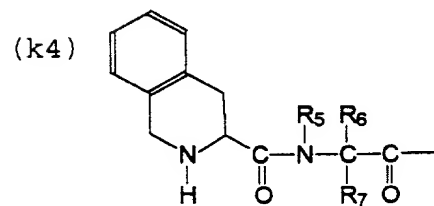
;



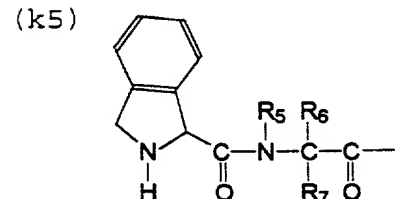
;



;

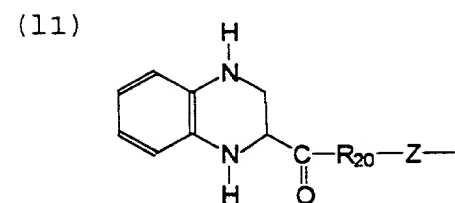


; and

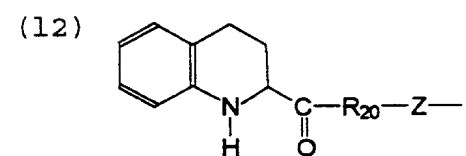


.

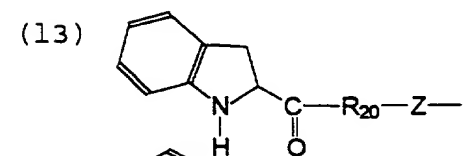
Preferred forms of the R<sub>1</sub> group (1) are:



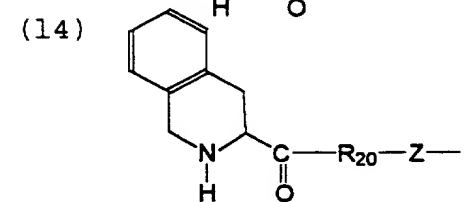
;



;



;

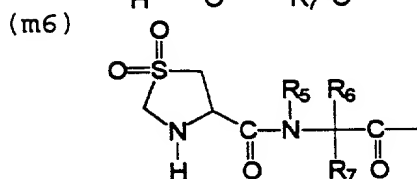
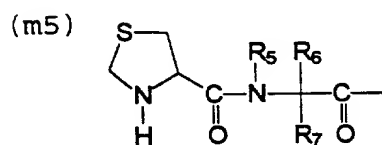
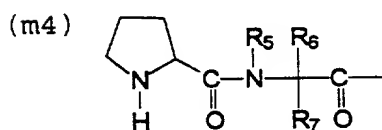
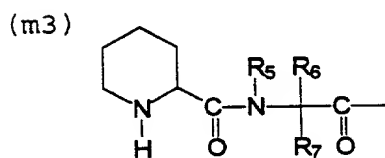
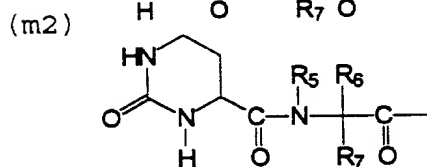
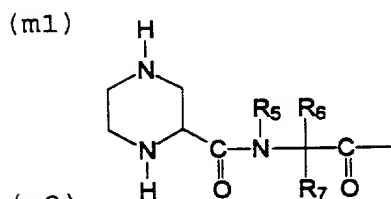


; and

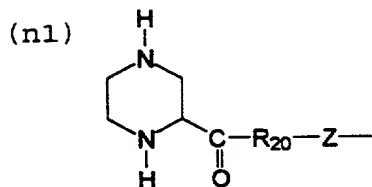
(15)

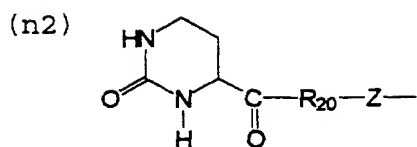
Chemical structure (15) is a fluorene derivative. It consists of a fluorene core (three fused rings: two benzene rings and one five-membered ring) with a carbonyl group ( $\text{C}=\text{O}$ ) attached to the 9-position. The nitrogen atom of the amide group is bonded to a hydrogen atom ( $\text{H}$ ). The carbonyl carbon is also bonded to an  $\text{R}_{20}$  group, which is further connected to a  $\text{Z}$  group.

Preferred forms of the R<sub>1</sub> group (m) are:

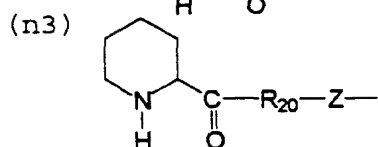


Preferred forms of the R<sub>1</sub> group (n) are:

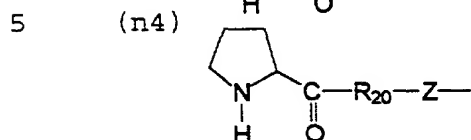




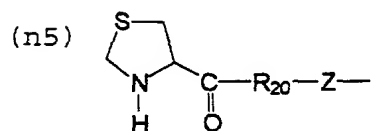
;



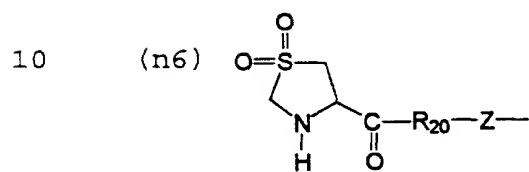
;



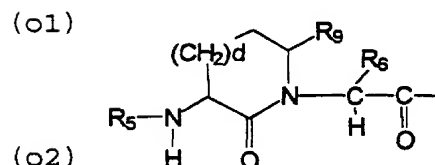
;



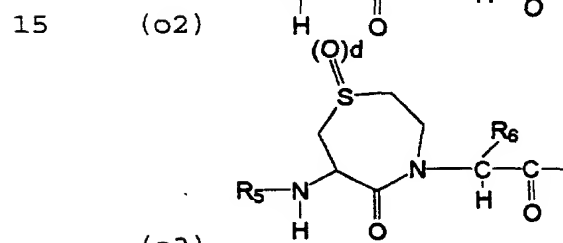
; and



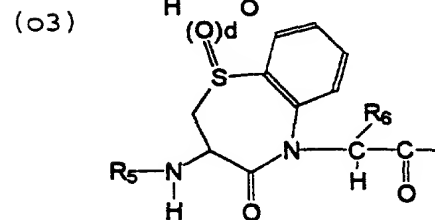
Preferred forms of the R<sub>1</sub> group (o) are:



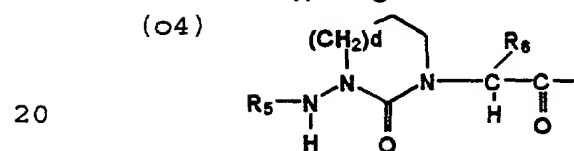
;



;



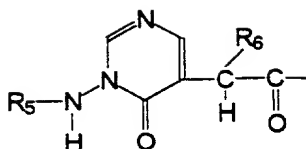
;



; and

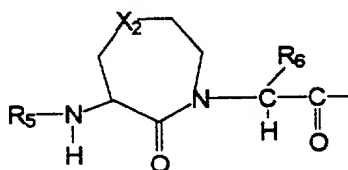
09886773.062404

(o5)



A preferred form of the R<sub>1</sub> group (o) of  
embodiment B is:

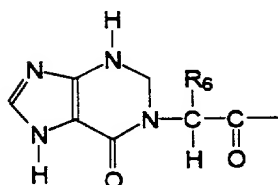
(o6)



wherein X<sub>2</sub> is -O-, -S-, -SO<sub>2</sub>-, or -NH-.

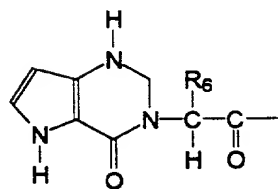
For embodiments A and B, preferred forms of  
the R<sub>1</sub> group (p) are:

(p1)



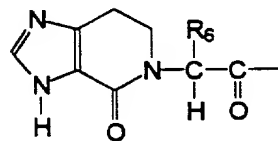
;

(p2)



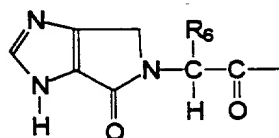
;

(p3)



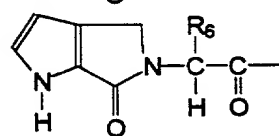
;

(p4)



; and

(p5)

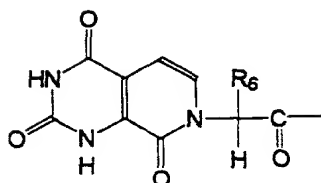


.

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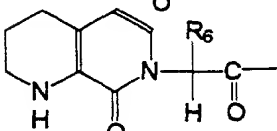
Preferred forms of the  $R_1$  group (q) are:

(q1)



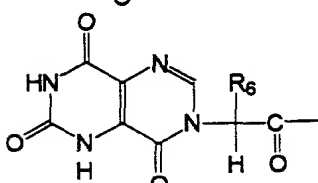
;

(q2)



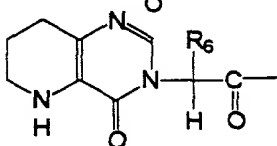
;

(q3)



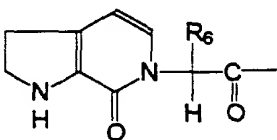
;

(q4)



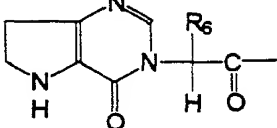
;

(q5)



; and

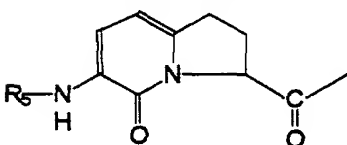
(q6)



.

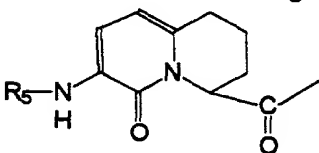
Preferred forms of the  $R_1$  group (r) are:

(r1)



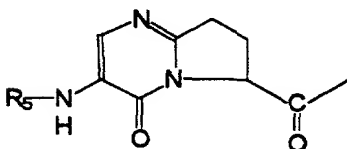
;

(r2)



;

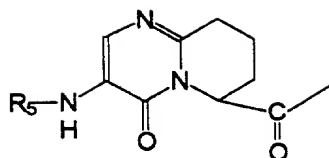
(r3)



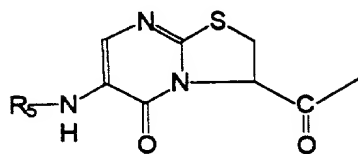
;

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(r4)

*i*

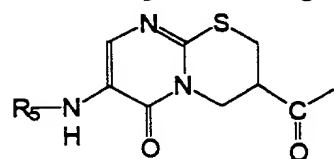
(r5)



i

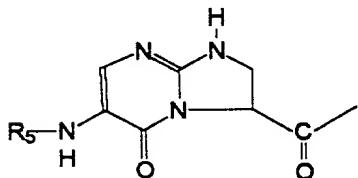
5

(r6)



; and

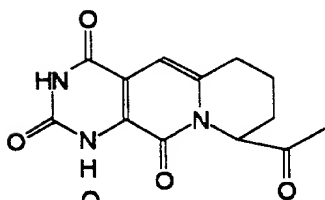
(r7)



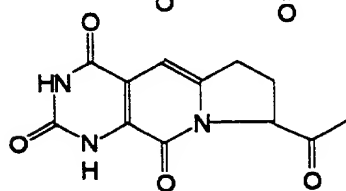
Preferred forms of the R<sub>1</sub> group (s) are:

10

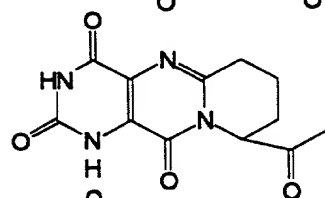
(s1)



(s2)



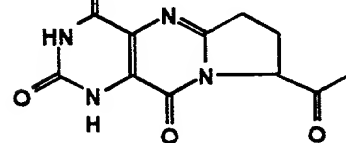
(S3)



15

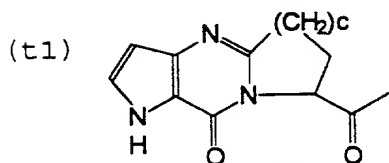
; and

(S4)

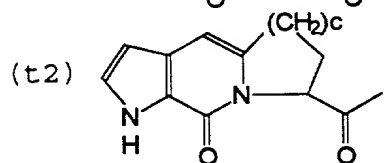




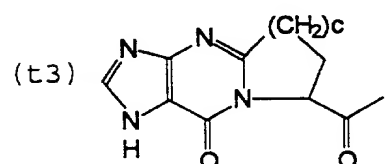
Preferred forms of the R<sub>1</sub> group (t) are:



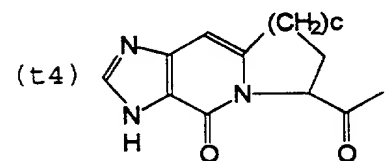
;



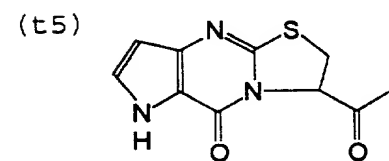
;



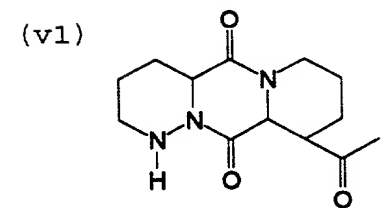
;



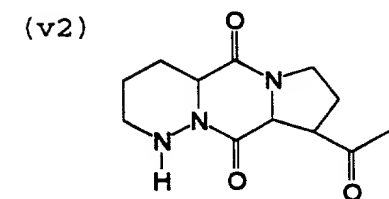
; and



Preferred forms of the R<sub>1</sub> group (v) are:

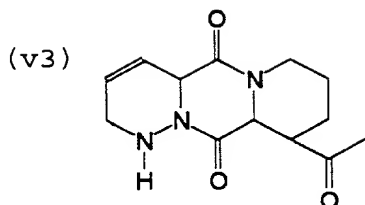


;

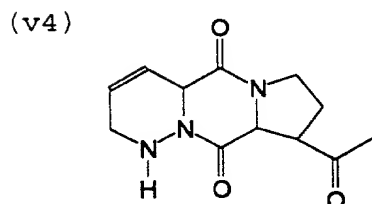


;

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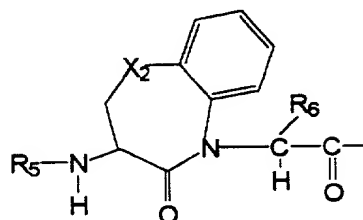
; and



5

A preferred form of the R1 group (w) of embodiment B is:

(w1)



10

wherein X<sub>2</sub> is -O-, -S-, -SO<sub>2</sub>- or -NH-.

The preferred compounds of embodiments A and B of this invention are those which employ formula α, wherein:

15

X<sub>1</sub> is CH;

g is O;

J is -H;

m is 0 or 1 and T is -Ar<sub>3</sub>, -CO-CO<sub>2</sub>H, -CO<sub>2</sub>H or any bioisosteric replacement for -CO<sub>2</sub>H, or

20

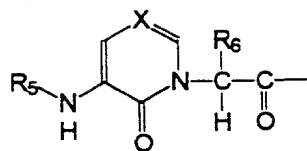
m is 1 or 2 and T is -OH, -CF<sub>3</sub>, or -CO<sub>2</sub>H;

more preferably m is 1 and T is -CO<sub>2</sub>H;

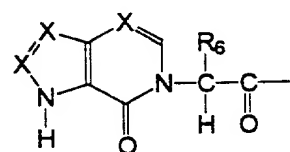
09886779.062104

R<sub>1</sub> is

(c)

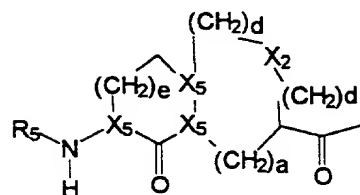


(d)

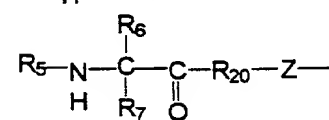


5

(e)

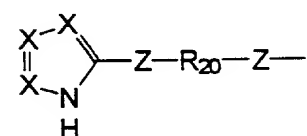


(f)

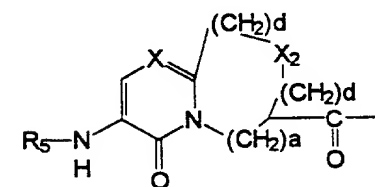


10

(g)



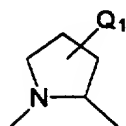
(r)



15

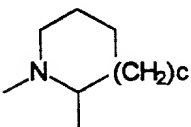
R<sub>20</sub> is

(aa1)

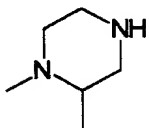


20

(aa2)



(aa3)



, or

(dd)



wherein ring C is benzo;

$R_3$  is

5             $-CO-R_{13}$ , or  
               $-CO-CO-N$   
                               $\begin{matrix} /R_5 \\ \backslash R_{10} \end{matrix}$ ;

10            most preferably  $R_3$  is any one of 1), 2) or 3) as follows: 1)  $-CO-Ar_2$ , 2)  $-CO-R_9$  where  $R_9$  is  $C_{3-6}$  alkyl substituted with two  $Ar_1$  groups or one  $Ar_1$  group itself substituted with an  $Ar_1$  group,  $-C_{1-2}-Ar_1$ ,  $-Cl$ ,  $-CH_3$ , or  $-CF_3$ , or 3)  $-(CH_2)_{1,2}-T_1-R_9$  where  $T_1$  is  $-O-$  or  $-S-$  and  $R_9$  is  $C_{1-2}$  alkyl substituted with two  $Ar_1$  groups or one  $Ar_1$  group itself substituted with an  $Ar_1$  group,  $C_{1-2}-Ar_1$ ,  
 15             $-Cl$ ,  $-CH_3$ , or  $-CF_3$ ;

$R_4$  is  $-H$  or  $-R_9$ ;

$T_1$  is

20             $-O-$ ,  
               $-S-$ ,  
               $-CO-$ ,  
               $-O-CO-$ , or  
               $-SO_2-$ ;

25            when  $R_1$  is (a), (b), (k), or (m),  $R_5$  is preferably  $-Ar_1$  or  $C_{1-4}-Ar_1$ ;

when  $R_1$  is (c), (e), (f), (o), or (r),  $R_5$  is preferably  $-SO_2-Ar_1$ ,  $-SO_2-R_9$ , or  $-CO-C_{1-4}-Ar_1$ ;

$R_7$  is -H and  $R_6$  is  $C_{1-4}-Ar_1$ ;

5  $R_{10}$  is -H or a  $C_{1-3}$  straight or branched alkyl group;

$R_{13}$  is  $-Ar_2$ ;

$Ar_1$  is phenyl, naphthyl, pyridyl, benzothiazolyl, thienyl, benzothienyl, benzoxazolyl, 2-indanyl, or indolyl;

10  $Ar_2$  is preferably substituted with  $-Ar_1$ , or  $-C_{1-4}-Ar_1$ ;

$Ar_3$  is phenyl, thiophene, thiazole, pyridine, or oxazole; and

15  $Q_1$  is  $-R_9$  or  $-(CH_2)_{1,2}-T_1-(CH_2)_{1-3}-Ar_1$  where  $T_1$  is -O- or -S-.

In connection with this continuation-in-part, we now prefer the compounds of embodiment B of this invention which employ formula  $\alpha$ , wherein:

$X_1$  is -CH;

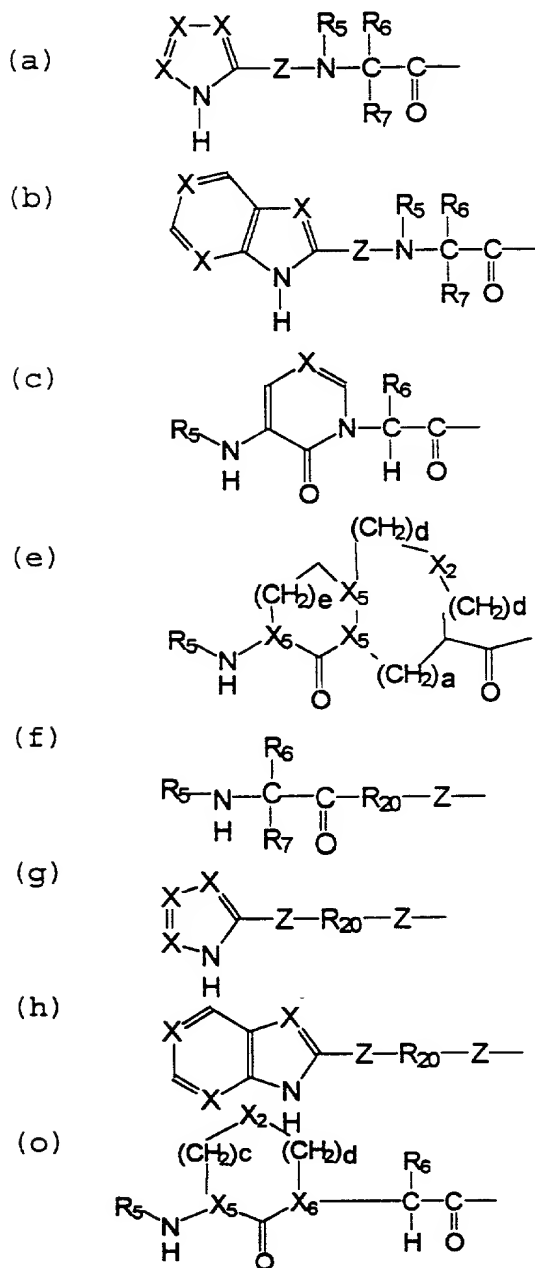
20 g is O;

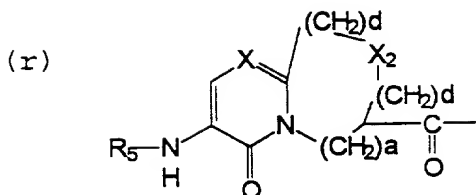
J is -H;

m is 0 or 1 and T is  $-CO-CO_2H$ , or any bioisosteric replacement for  $-CO_2H$ ; or

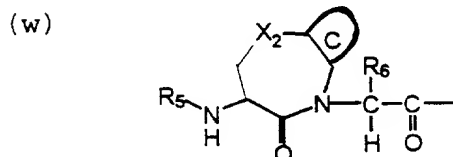
m is 1 and T is  $-\text{CO}_2\text{H}$ ;

$\text{R}_1$  is selected from the group consisting of the following formulae, in which any ring may optionally be singly or multiply substituted at any carbon by  $\text{Q}_1$ , at any nitrogen by  $\text{R}_5$ , or at any atom by  $=\text{O}$ ,  $-\text{OH}$ ,  $-\text{CO}_2\text{H}$ , or halogen, and wherein (e) is optionally benzofused:





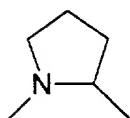
, or



;

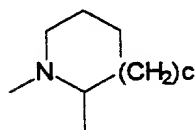
R<sub>20</sub> is

(aa1)



, or

(aa2)



and c is 1;

ring C is benzo optionally substituted with  
-C<sub>1-3</sub> alkyl, -O-C<sub>1-3</sub> alkyl, -Cl, -F or -CF<sub>3</sub>;

R<sub>3</sub> is:

-CO-R<sub>13</sub>, or

-CO-CO-N<sup>/R<sub>9</sub></sup><sub>\R<sub>10</sub></sub>;

more preferably R<sub>3</sub> is any one of 1), 2) or 3) as  
follows: 1) -CO-Ar<sub>2</sub>; 2) -CO-R<sub>9</sub> where R<sub>9</sub> is C<sub>1-5</sub> alkyl  
substituted with an Ar<sub>1</sub>; or 3) -CH<sub>2</sub>-T<sub>1</sub>-R<sub>9</sub> where T<sub>1</sub> is -O-  
or -S- and R<sub>9</sub> is C<sub>1-2</sub> alkyl substituted with one Ar<sub>1</sub>  
group;

R<sub>4</sub> is -H or -R<sub>9</sub>;

T<sub>1</sub> is:

5           -O-,  
          -S-,  
          -CO-,  
          -O-CO-, or  
          -SO<sub>2</sub>-;

when R<sub>1</sub> is (a) or (b), R<sub>5</sub> is preferably -H, and  
when R<sub>1</sub> is (c), (e), (f), (o), (r), (w), (x) or  
(y), R<sub>5</sub> is preferably:

10           -CO-Ar<sub>1</sub>  
          -SO<sub>2</sub>-Ar<sub>1</sub>,  
          -CO-NH<sub>2</sub>,  
          -CO-NH-Ar<sub>1</sub>  
          -CO-R<sub>9</sub>,  
15           -CO-O-R<sub>9</sub>,  
          -SO<sub>2</sub>-R<sub>9</sub>, or  
          -CO-NH-R<sub>9</sub>,

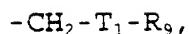
20           R<sub>7</sub> is -H and R<sub>6</sub> is  
          -H,  
          -R<sub>9</sub> or  
          -Ar<sub>1</sub>;

25           R<sub>9</sub> is C<sub>1-6</sub> straight or branched alkyl group  
          optionally substituted with =O and optionally  
          substituted with -Ar<sub>1</sub>;

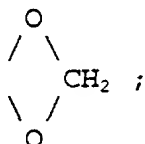
          R<sub>10</sub> is -H or a C<sub>1-3</sub> straight or branched alkyl  
          group;

30           R<sub>13</sub> is:  
          -H,  
          -R<sub>9</sub>,  
          -Ar<sub>2</sub>, or

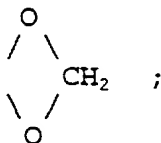




more preferably where  $-\text{Ar}_2$  is  
(hh) and where (hh) is optionally substituted singly or  
multiply with  $-\text{C}_{1-6}$  alkyl,  $-\text{O}-\text{C}_{1-6}$  alkyl,  
5  $-\text{NH}-\text{C}_{1-6}$  alkyl,  $-\text{N}-(\text{C}_{1-6} \text{ alkyl})_2$ ,  $-\text{S}-\text{C}_{1-6}$  alkyl,  $-\text{Cl}$ ,  
 $-\text{F}$ ,  $-\text{CF}_3$ , or

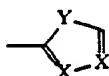


$\text{Ar}_1$  is phenyl, naphthyl, pyridyl, benzothiazolyl,  
thienyl, benzothienyl, benzoxazolyl, 2-indanyl, or  
indolyl substituted with  $-\text{O}-\text{C}_{1-3}$  alkyl,  $-\text{NH}-\text{C}_{1-3}$  alkyl, -  
15  $\text{N}-(\text{C}_{1-3} \text{ alkyl})_2$ ,  $-\text{Cl}$ ,  $-\text{F}$ ,  $-\text{CF}_3$ ,  
 $-\text{C}_{1-3}$  alkyl, or

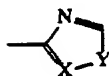


preferably where  $\text{Ar}_2$  is:

(ii)

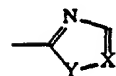


(jj)



, or

(kk)



each X is independently selected from the group  
30 consisting of  $=\text{N}-$ , and  $=\text{CH}-$ ;

each  $X_2$  is independently selected from the group consisting of  $-O-$ ,  $-CH_2-$ ,  $-NH-$ ,  $-S-$ ,  $-SO-$ , and  $-SO_2-$ ;

each  $X_5$  is independently selected from the group consisting of  $-CH-$  and  $-N-$ ;

5



$X_6$  is  $-CH-$  or  $-N-$ ; and



$Z$  is  $C=O$ ;

10

provided that when

$R_1$  is (f),

$R_6$  is an  $\alpha$ -amino acid side chain residue, and

$R_7$  is  $-H$ ,

then (aa1) and (aa2) must be substituted with  $Q_1$ ;

15

also provided that when

$R_1$  is (o),

$g$  is 0,

$J$  is  $-H$ ,

20

$m$  is 1,

$R_6$  is an  $\alpha$ -amino acid side chain residue,

$R_7$  is  $-H$ ,

$X_2$  is  $-CH_2-$ ,

$X_5$  is  $-CH-$ ,

25

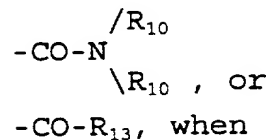


$X_6$  is  $-N-$ , and



30

$R_3$  is



35

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R<sub>13</sub> is:

- CH<sub>2</sub>-O-CO-Ar<sub>1</sub>,
- CH<sub>2</sub>-S-CO-Ar<sub>1</sub>,
- CH<sub>2</sub>-O-Ar<sub>1</sub>,
- 5        -CH<sub>2</sub>-S-Ar<sub>1</sub>, or
- R<sub>4</sub> when -R<sub>4</sub> is -H;

then the ring of the R<sub>1</sub>(o) group must be substituted with Q<sub>1</sub> or benzofused; and

provided that when

- 10        R<sub>1</sub> is (w),
- g is 0,
- J is -H,
- m is 1,
- T is -CO<sub>2</sub>H,
- 15        X<sub>2</sub> is O,
- R<sub>5</sub> is benzyloxycarbonyl, and
- ring C is benzo,

then R<sub>3</sub> cannot be -CO-R<sub>13</sub> when:

- R<sub>13</sub> is -CH<sub>2</sub>-O-Ar<sub>1</sub> and
- 20        Ar<sub>1</sub> is 1-phenyl-3-trifluoromethyl-pyrazole-5-yl,
- wherein the phenyl is optionally substituted with a
- chlorine atom;
- or when R<sub>13</sub> is -CH<sub>2</sub>-O-CO-Ar<sub>1</sub>, wherein
- Ar<sub>1</sub> is 2,6-dichlorophenyl.

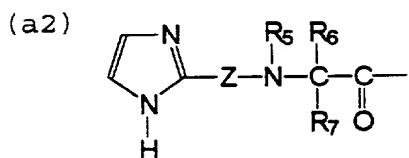
- 25        A preferred form of R<sub>13</sub> is -CH<sub>2</sub>-O-R<sub>9</sub>, wherein
- R<sub>9</sub> is a C<sub>1-6</sub> straight or branched alkyl group optionally
- substituted with =O and optionally substituted with Ar<sub>1</sub>;

- another preferred form of R<sub>13</sub> is CH<sub>2</sub>-S-R<sub>9</sub>, wherein
- R<sub>9</sub> is a C<sub>1-6</sub> straight or branched alkyl group optionally
- 30        substituted with Ar<sub>1</sub>;

another preferred form of  $R_{13}$  is  $CH_2-O-R_9$  wherein  $R_9$  is a  $C_{1-6}$  straight or branched alkyl group optionally substituted with  $Ar_1$ ;

another preferred form of  $R_{13}$  is H.

5 A more preferred form of the  $R_1$  group (a) is:

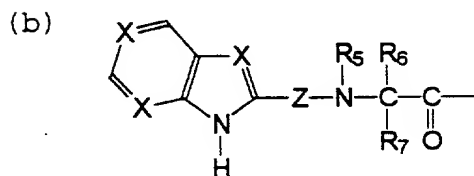


optionally substituted with  $Q_1$ , wherein  $R_5$  is -H;

$R_7$  is -H; and

10 Z is C=O;

a more preferred form of the  $R_1$  group (b) is:

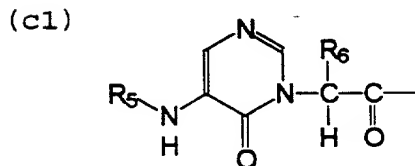


optionally substituted with  $Q_1$ , wherein  $R_5$  is -H;

15  $R_7$  is -H; and

Z is C=O;

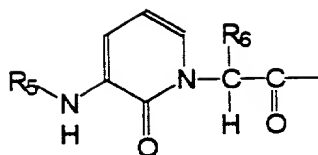
more preferred forms of the  $R_1$  group (c) are:



20

, and

(c2)



provided that when  $R_1$  is (c1),

$g$  is 0,

$J$  is -H,

$m$  is 1,

$T$  is  $-\text{CO}_2\text{H}$ ,

$X$  is N,

$R_5$  is benzyloxycarbonyl, and

$R_6$  is -H,

then  $R_3$  cannot be  $-\text{CO}-R_{13}$  when

$R_{13}$  is  $-\text{CH}_2-\text{O}-\text{Ar}_1$  and

$\text{Ar}_1$  is 1-phenyl-3-trifluoromethyl-pyrazole-5-yl wherein the phenyl is optionally substituted with a chlorine atom; or when

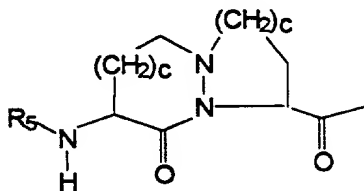
$R_{13}$  is  $-\text{CH}_2-\text{O}-\text{CO}-\text{Ar}_1$ , wherein

$\text{Ar}_1$  is 2,6-dichlorophenyl,

and wherein the 2-position of the scaffold ring is substituted with para-fluoro-phenyl;

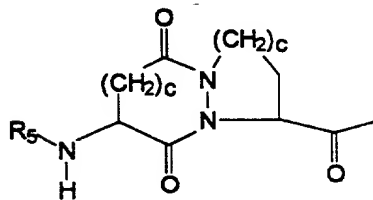
more preferred forms of the  $R_1$  group (e) are:

(e1)



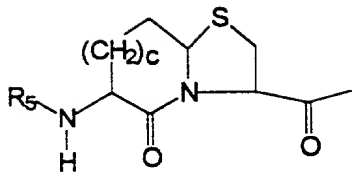
, and

(e2)



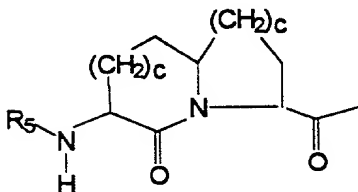
wherein  $c$  is 2; and

(e4)



, and

(e7)



which is optionally  
benzofused,

wherein c is 1 or 2;

provided that when R<sub>1</sub> is (e4),

g is 0,

J is -H,

m is 1,

T is -CO<sub>2</sub>H,

R<sub>5</sub> is benzyloxycarbonyl, and

c is 1,

then R<sub>3</sub> cannot be -CO-R<sub>13</sub> when

R<sub>13</sub> is -CH<sub>2</sub>-O-Ar<sub>1</sub> and

Ar<sub>1</sub> is 1-phenyl-3-trifluoromethyl-pyrazole-  
5-yl wherein the phenyl is optionally substituted with  
a chlorine atom; or when

R<sub>13</sub> is -CH<sub>2</sub>-O-CO-Ar<sub>1</sub>, wherein

Ar<sub>1</sub> is 2,6-dichlorophenyl,

and wherein the 2-position of the scaffold ring is  
substituted with para-fluoro-phenyl; and

also provided that when

R<sub>1</sub> is (e7),

g is 0,

J is -H,

m is 1,

T is  $-\text{CO}_2\text{H}$ ,  $-\text{CO-NH-OH}$ , or a bioisosteric replacement for  $-\text{CO}_2\text{H}$ ,

$\text{R}_5$  is a protective group for the N atom of an  $\alpha$ -amino acid side chain residue, and

5 each c is 1,

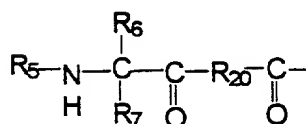
then  $\text{R}_3$  cannot be  $-\text{CO-R}_{13}$  when

$\text{R}_{13}$  is:

- 10  $-\text{CH}_2-\text{O}-\text{CO-Ar}_1$ ,  
 $-\text{CH}_2-\text{S}-\text{CO-Ar}_1$ ,  
 $-\text{CH}_2-\text{O-Ar}_1$ , or  
 $-\text{CH}_2-\text{S-Ar}_1$ .

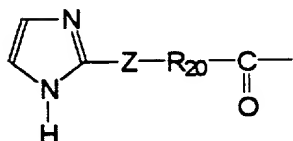
a more preferred form of the  $\text{R}_1$  group (f) is

(f1)



15 a more preferred form of the  $\text{R}_1$  group (g) is:

(g2)



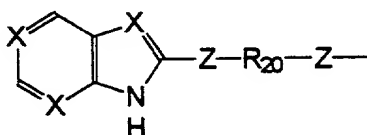
; wherein

$\text{R}_{20}$  is (aa1) optionally substituted singly or multiply with  $\text{Q}_1$ ; and

20 Z is  $\text{C=O}$ ;

a more preferred form of the  $\text{R}_1$  group (h) is:

(h)



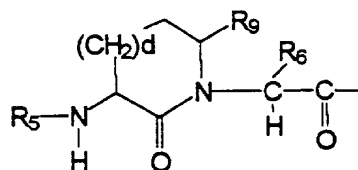
; wherein

R<sub>20</sub> is (aa1) optionally substituted singly or multiply with Q<sub>1</sub>; and

Z is C=O;

more preferred forms of the R<sub>1</sub> group (o) are:

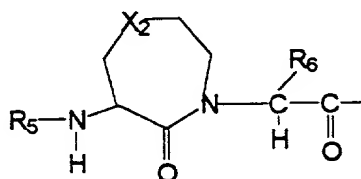
5 (o1)



;

wherein d is 1 or 2; and

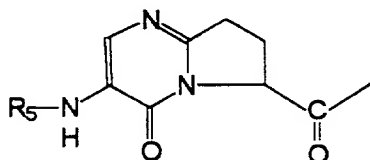
(o6)



;

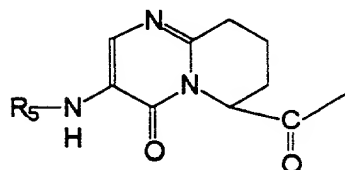
10 more preferred forms of the R<sub>1</sub> group (r) are:

(r3)



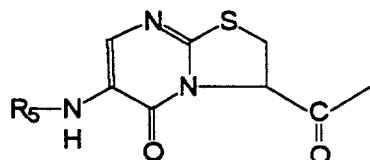
;

(r4)



; and

15 (r5)

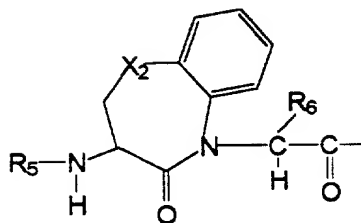


optionally substituted with Q<sub>1</sub>;



a more preferred form of the R<sub>1</sub> group (w) is:

(w1)



; wherein

X<sub>2</sub> is:

5

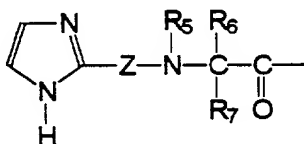
-NH-,  
-S- ,  
-O- , or  
-SO<sub>2</sub>-;

optionally substituted with R<sub>5</sub> or Q<sub>1</sub> at X<sub>2</sub>  
10 when X<sub>2</sub> is -N-; and

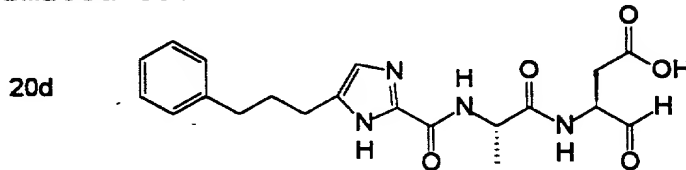
ring C is benzo substituted with -C<sub>1-3</sub> alkyl,  
-O-C<sub>1-3</sub> alkyl, -Cl, -F or -CF<sub>3</sub>.

When R<sub>1</sub> is:

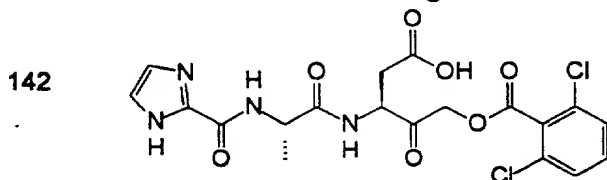
(a2)



15 preferred compounds of this invention include but are  
not limited to:

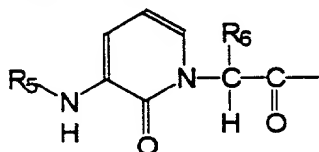


; and

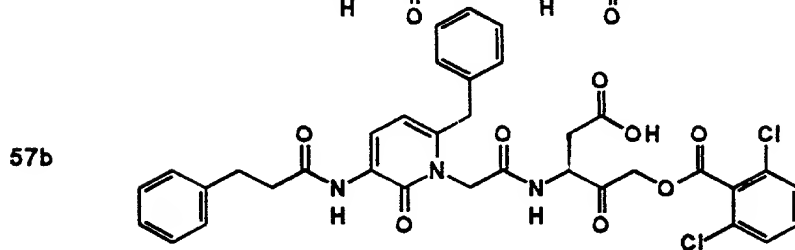
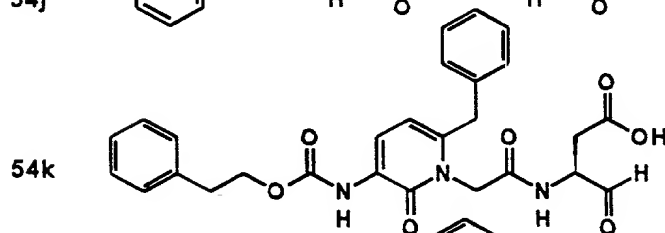
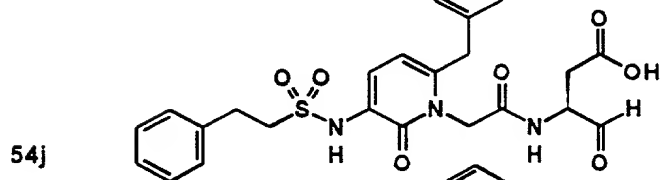
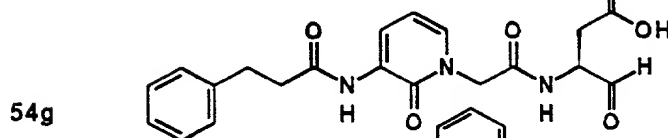
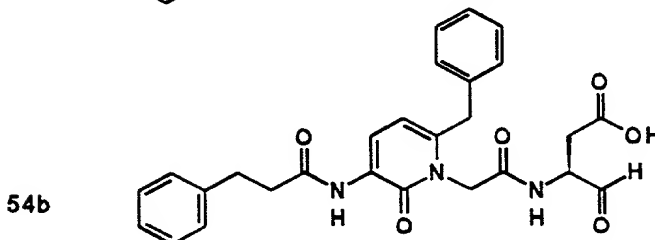
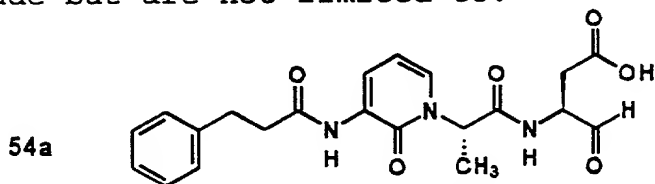


A preferred compound of embodiment B of this invention employs formula  $\alpha$ , wherein the  $R_1$  is:

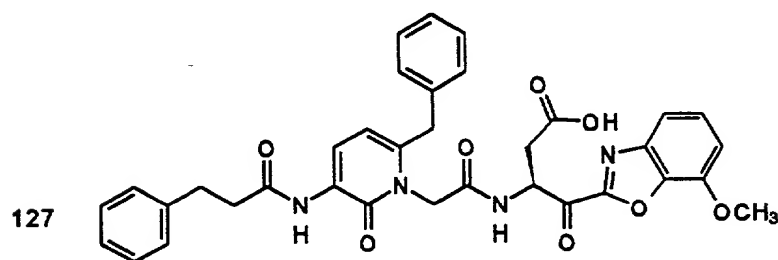
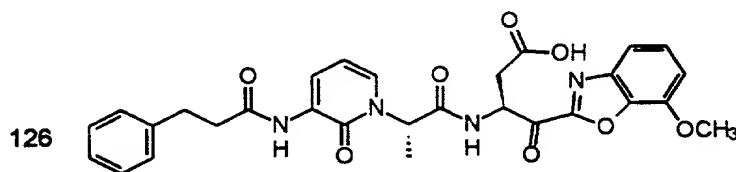
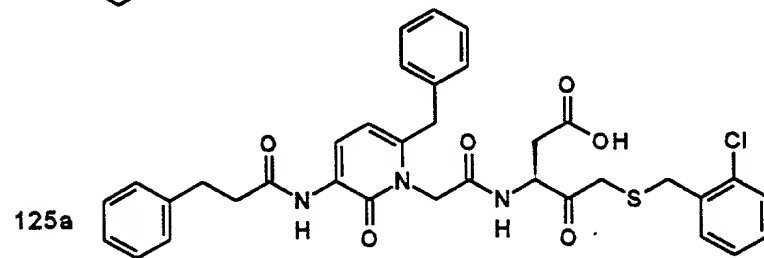
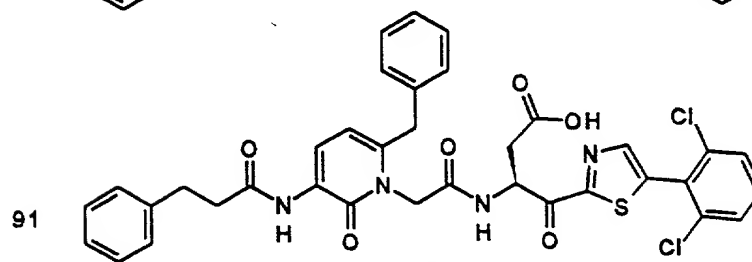
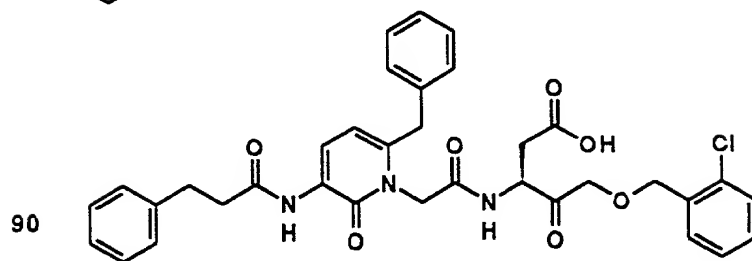
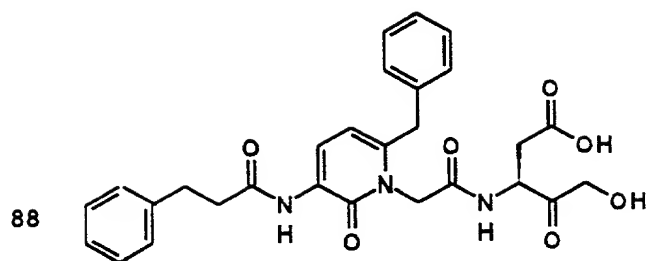
(c2)



5 Preferred compounds of this embodiment  
include but are not limited to:



1990-1991		1991-1992		1992-1993		1993-1994		1994-1995		1995-1996		1996-1997		1997-1998		1998-1999		1999-2000		2000-2001		2001-2002		2002-2003		2003-2004		2004-2005		2005-2006		2006-2007		2007-2008		2008-2009		2009-2010		2010-2011		2011-2012		2012-2013		2013-2014		2014-2015		2015-2016		2016-2017		2017-2018		2018-2019		2019-2020		2020-2021		2021-2022		2022-2023		2023-2024		2024-2025		2025-2026		2026-2027		2027-2028		2028-2029		2029-2030		2030-2031		2031-2032		2032-2033		2033-2034		2034-2035		2035-2036		2036-2037		2037-2038		2038-2039		2039-2040		2040-2041		2041-2042		2042-2043		2043-2044		2044-2045		2045-2046		2046-2047		2047-2048		2048-2049		2049-2050		2050-2051		2051-2052		2052-2053		2053-2054		2054-2055		2055-2056		2056-2057		2057-2058		2058-2059		2059-2060		2060-2061		2061-2062		2062-2063		2063-2064		2064-2065		2065-2066		2066-2067		2067-2068		2068-2069		2069-2070		2070-2071		2071-2072		2072-2073		2073-2074		2074-2075		2075-2076		2076-2077		2077-2078		2078-2079		2079-2080		2080-2081		2081-2082		2082-2083		2083-2084		2084-2085		2085-2086		2086-2087		2087-2088		2088-2089		2089-2090		2090-2091		2091-2092		2092-2093		2093-2094		2094-2095		2095-2096		2096-2097		2097-2098		2098-2099		2099-2100		2100-2101		2101-2102		2102-2103		2103-2104		2104-2105		2105-2106		2106-2107		2107-2108		2108-2109		2109-2110		2110-2111		2111-2112		2112-2113		2113-2114		2114-2115		2115-2116		2116-2117		2117-2118		2118-2119		2119-2120		2120-2121		2121-2122		2122-2123		2123-2124		2124-2125		2125-2126		2126-2127		2127-2128		2128-2129		2129-2130		2130-2131		2131-2132		2132-2133		2133-2134		2134-2135		2135-2136		2136-2137		2137-2138		2138-2139		2139-2140		2140-2141		2141-2142		2142-2143		2143-2144		2144-2145		2145-2146		2146-2147		2147-2148		2148-2149		2149-2150		2150-2151		2151-2152		2152-2153		2153-2154		2154-2155		2155-2156		2156-2157		2157-2158		2158-2159		2159-2160		2160-2161		2161-2162		2162-2163		2163-2164		2164-2165		2165-2166		2166-2167		2167-2168		2168-2169		2169-2170		2170-2171		2171-2172		2172-2173		2173-2174		2174-2175		2175-2176		2176-2177		2177-2178		2178-2179		2179-2180		2180-2181		2181-2182		2182-2183		2183-2184		2184-2185		2185-2186		2186-2187		2187-2188		2188-2189		2189-2190		2190-2191		2191-2192		2192-2193		2193-2194		2194-2195		2195-2196		2196-2197		2197-2198		2198-2199		2199-2200		2200-2201		2201-2202		2202-2203		2203-2204		2204-2205		2205-2206		2206-2207		2207-2208		2208-2209		2209-2210		2210-2211		2211-2212		2212-2213		2213-2214		2214-2215		2215-2216		2216-2217	
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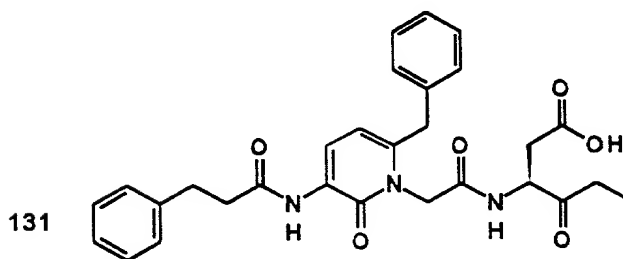
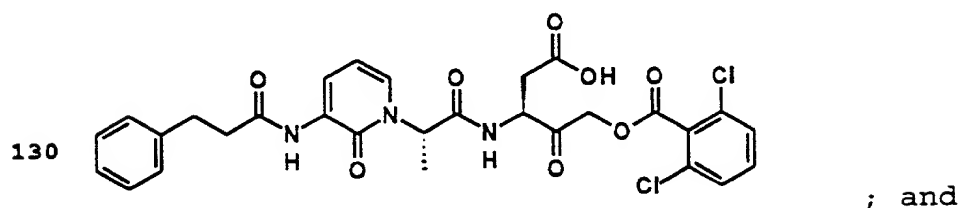
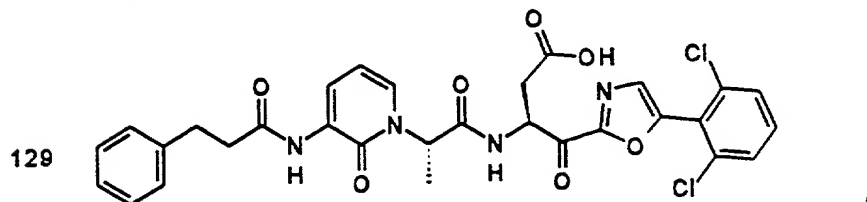
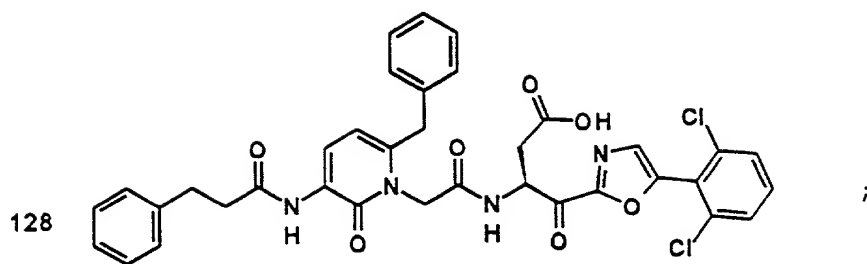


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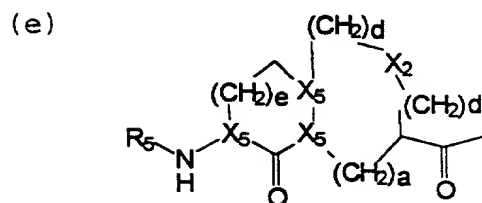
5

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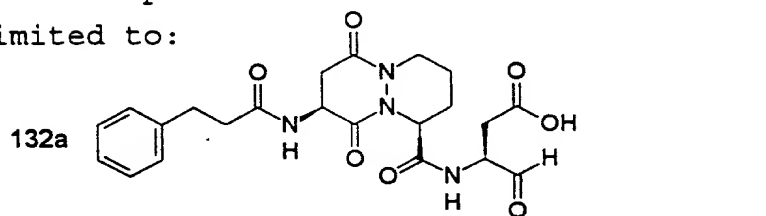
15



When  $R_1$  is:



20 preferred compounds of this invention include but are not limited to:



1

;

; and

20

(e1)

CC(=O)N1C(=O)N(CCC1)C(=O)N(R5)C(=O)N2CCCCC2

30

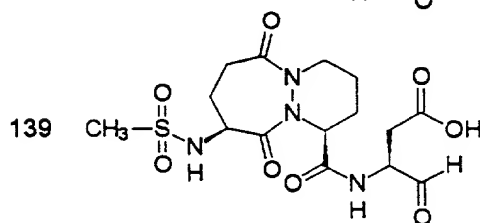
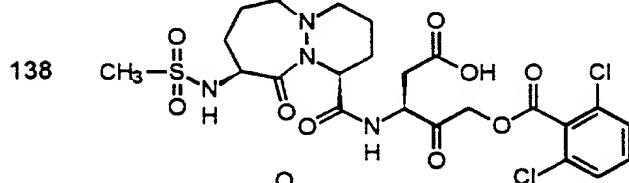
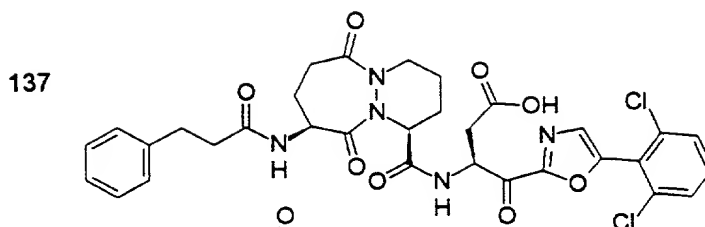
```
m is 1;
```

5

10

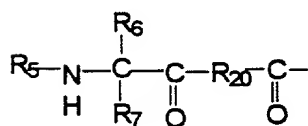
15

20

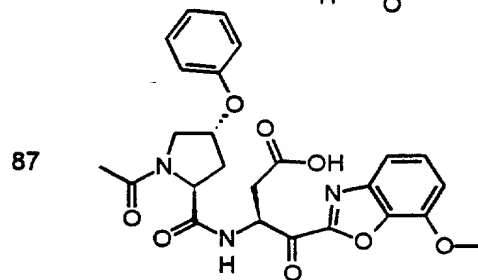
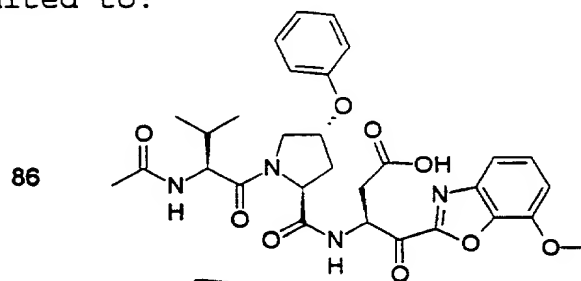


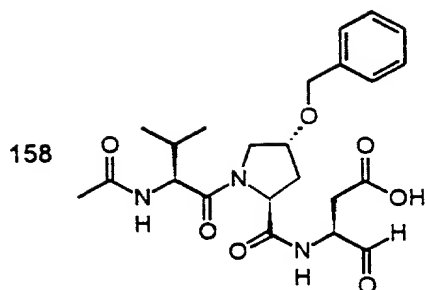
When  $R_1$  is:

(f1)

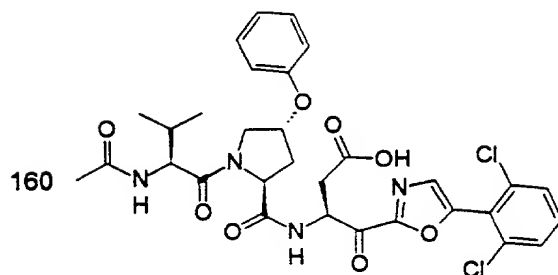


preferred compounds of this invention include but are not limited to:



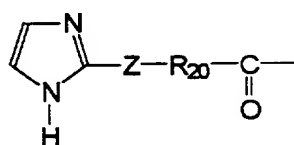


; and

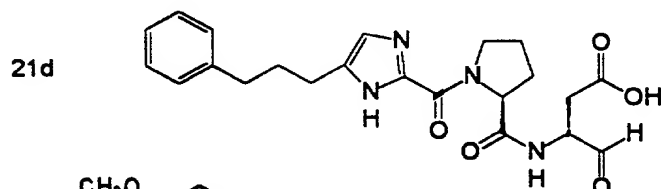


When  $R_1$  is:

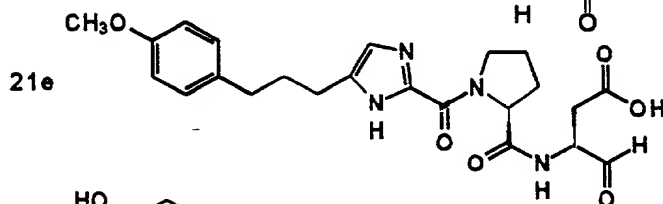
(g2)



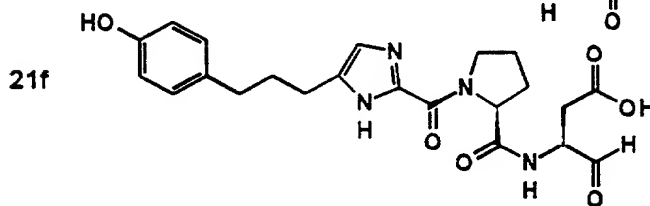
preferred compounds of this invention include but are not limited to:



;

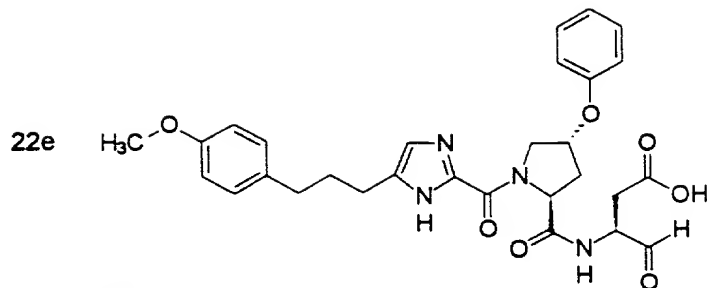


;

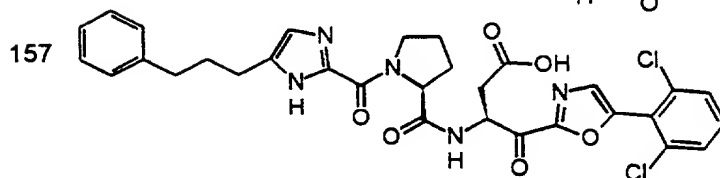


;



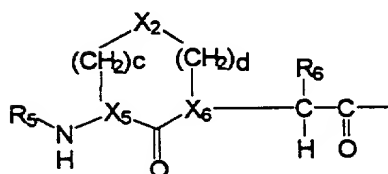


; and

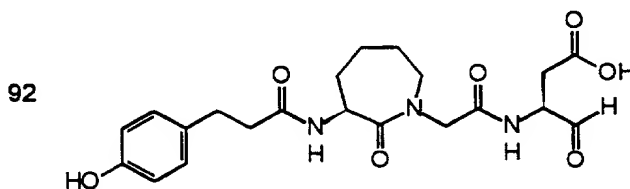


When  $R_1$  is:

(o)



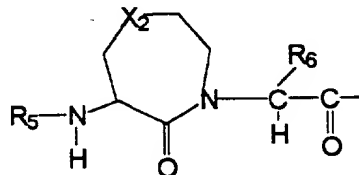
preferred compounds of this invention include but are not limited to:



A preferred compound of embodiment B of this invention employs formula  $\alpha$ , wherein:

$R_1$  is:

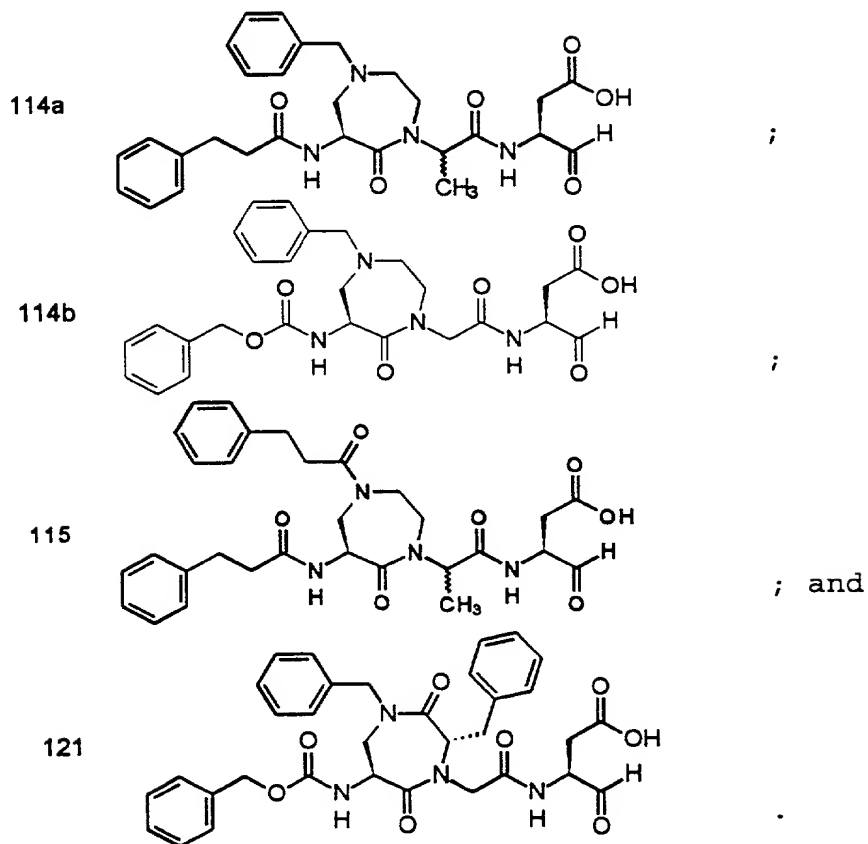
(o6)



$X_2$  is -NH-;

m is 1;  
T is  $-\text{CO}_2\text{H}$ ;  
 $\text{R}_3$  is  $-\text{CO}-\text{R}_{13}$ .

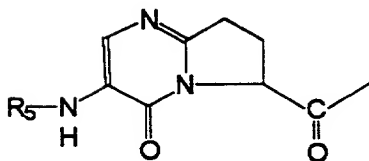
Preferred compounds of this embodiment  
5 include but are not limited to:



When  $\text{R}_1$  is:

15

(r3)

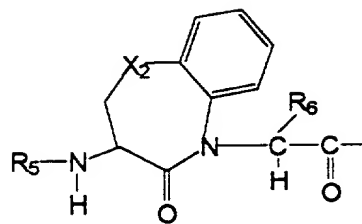


;



When  $R_1$  is:

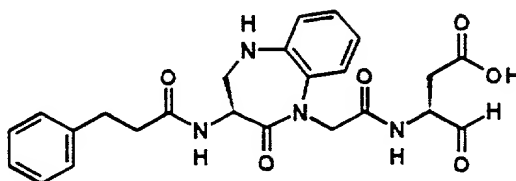
(w1)



;

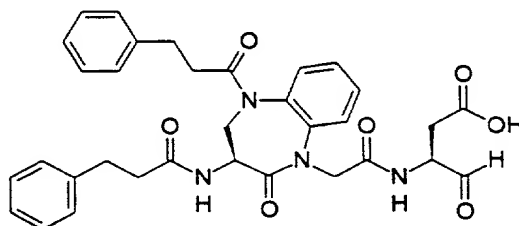
5 preferred compounds of this invention include but are not limited to:

106a



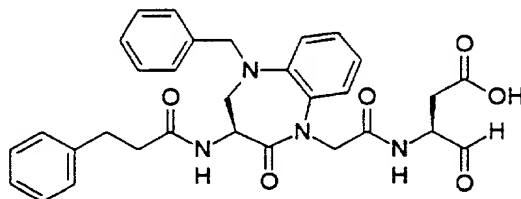
;

106b



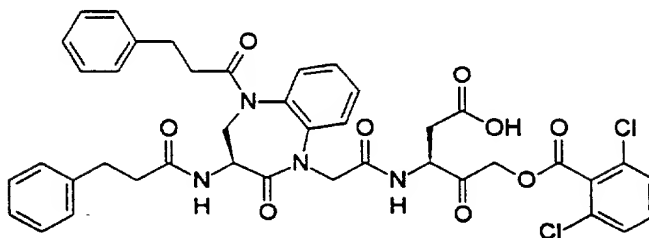
;

106c



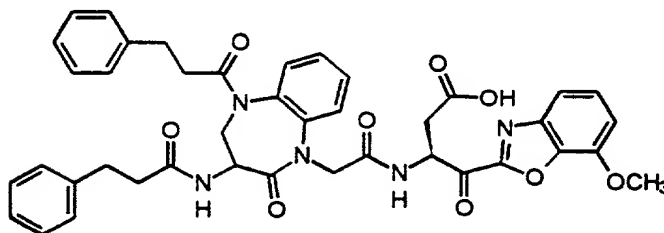
;

108a



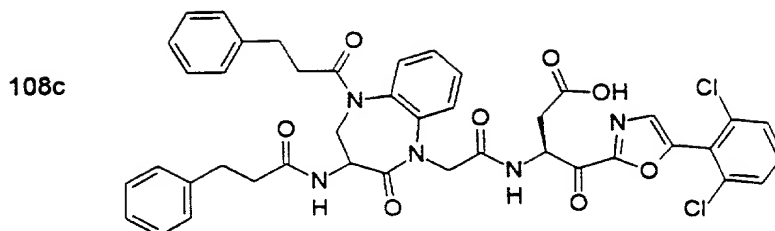
;

108b

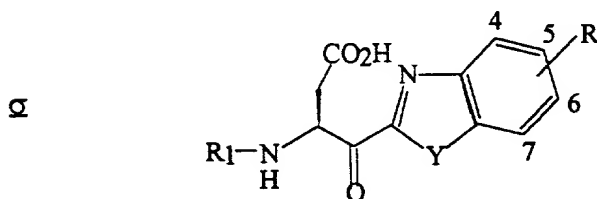


; and

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The ICE inhibitors of another embodiment (C) of this invention are represented by the formula  $\alpha$ :

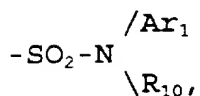


wherein the ring is optionally substituted with one or more R groups, preferably 0, 1 or 2; and wherein:

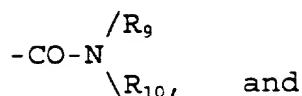
$R_1$  is  $R_5-(A)_p-$ ;

$R_5$  is selected from the group consisting of:

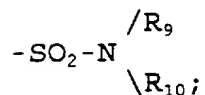
- H,
- Ar<sub>1</sub>,
- CO-Ar<sub>1</sub>,
- SO<sub>2</sub>-Ar<sub>1</sub>,
- R<sub>9</sub>,
- CO-R<sub>9</sub>,
- CO-O-R<sub>9</sub>,
- SO<sub>2</sub>-R<sub>9</sub>,
- CO-N<sup>/Ar<sub>1</sub></sup><sub>\R<sub>10</sub></sub>,



5



10



each A is independently selected from the group  
consisting of any  $\alpha$ -amino acid;

p is 0, 1, 2, 3 or 4;

Y is:

15

-O-,  
-S- or  
-NH;

R is:

20

-H,  
-O-C<sub>1-6</sub> alkyl,  
-NH(C<sub>1-6</sub> alkyl),  
-N(C<sub>1-6</sub> alkyl)<sub>2</sub>,  
-S-C<sub>1-6</sub> alkyl,  
-C<sub>1-6</sub> alkyl, or  
-Q<sub>2</sub>;

25

each R<sub>9</sub> is a C<sub>1-6</sub> straight or branched alkyl group  
optionally singly or multiply substituted by -OH, -F,  
or =O and optionally substituted with one or two Ar<sub>1</sub>  
groups;

30

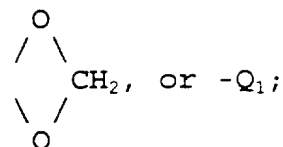
each R<sub>10</sub> is independently selected from the group  
consisting of -H or a C<sub>1-6</sub> straight or branched alkyl  
group;

each  $T_1$  is independently selected from the group consisting of:

- 5           -CH=CH-,  
          -O-,  
          -S-,  
          -SO-,  
          -SO<sub>2</sub>-,  
          -NR<sub>10</sub>-,  
          -NR<sub>10</sub>-CO-,  
10          -CO-,  
          -O-CO-,  
          -CO-O-,  
          -CO-NR<sub>10</sub>-,  
          -O-CO-NR<sub>10</sub>-,  
15          -NR<sub>10</sub>-CO-O-,  
          -NR<sub>10</sub>-CO-NR<sub>10</sub>-,  
          -SO<sub>2</sub>-NR<sub>10</sub>-,  
          -NR<sub>10</sub>-SO<sub>2</sub>-,           and  
          -NR<sub>10</sub>-SO<sub>2</sub>-NR<sub>10</sub>-,

- 20          each  $Ar_1$  is a cyclic group independently selected from the set consisting of an aryl group which contains 6, 10, 12, or 14 carbon atoms and between 1 and 3 rings, a cycloalkyl group which contains between 3 and 15 carbon atoms and between 1 and 3 rings, said  
25          cycloalkyl group being optionally benzofused, and a heterocycle group containing between 5 and 15 ring atoms and between 1 and 3 rings, said heterocycle group containing at least one heteroatom group selected from  
30          -O-, -S-, -SO-, -SO<sub>2</sub>-, =N-, and -NH-, said heterocycle group optionally containing one or more double bonds, said heterocycle group optionally comprising one or more aromatic rings, and said cyclic group optionally being singly or multiply substituted by: -NH<sub>2</sub>, -CO<sub>2</sub>H, -Cl, -F, -Br, -I, -NO<sub>2</sub>,

-CN, =O, -OH, -perfluoro C<sub>1-3</sub> alkyl,



each Q<sub>1</sub> is independently selected from the group consisting of:

-Ar<sub>1</sub>

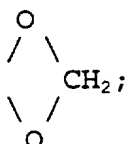
-R<sub>9</sub>,

-T<sub>1</sub>-R<sub>9</sub>,

and

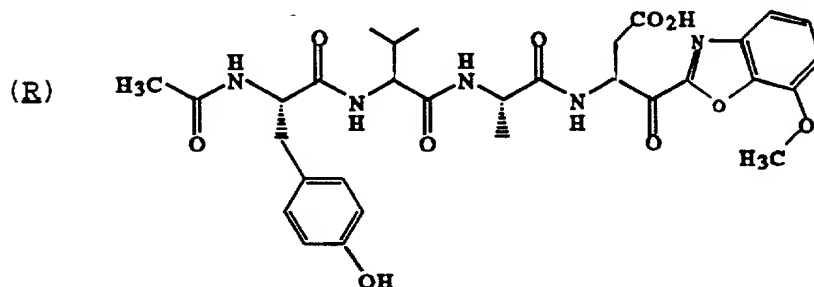
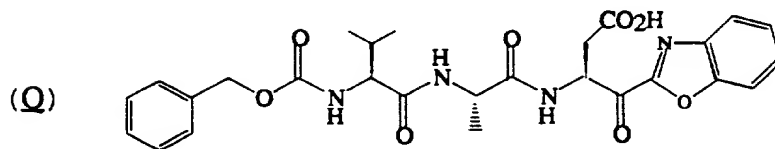
-(CH<sub>2</sub>)<sub>1,2,3</sub>-T<sub>1</sub>-R<sub>9</sub>;

each Q<sub>2</sub> is independently selected from the group consisting of -OH, -NH<sub>2</sub>, -CO<sub>2</sub>H, -Cl, -F, -Br, -I, -NO<sub>2</sub>, -CN, -CF<sub>3</sub>, and

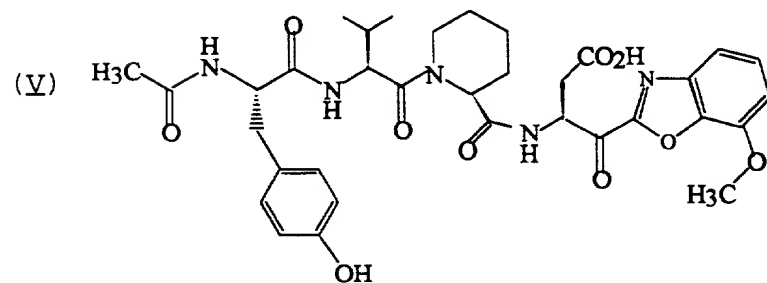
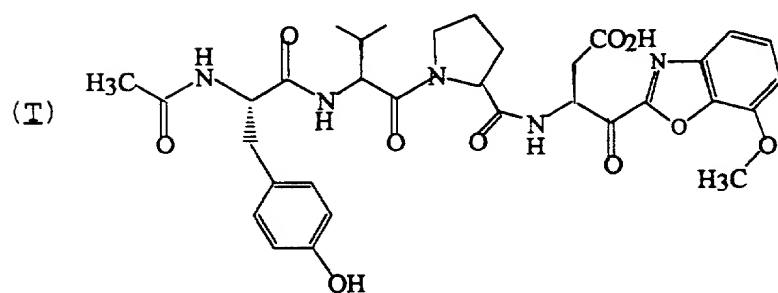
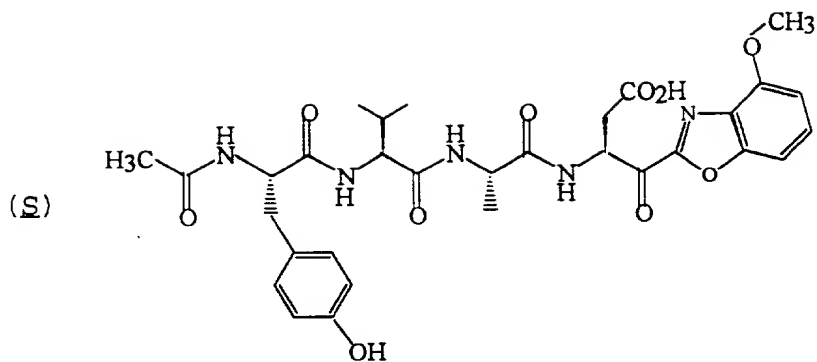


provided that when -Ar<sub>1</sub> is substituted with a Q<sub>1</sub> group which comprises one or more additional -Ar<sub>1</sub> groups, said additional -Ar<sub>1</sub> groups are not substituted with Q<sub>1</sub>.

Preferred compounds of embodiment C of this invention include but are not limited to:







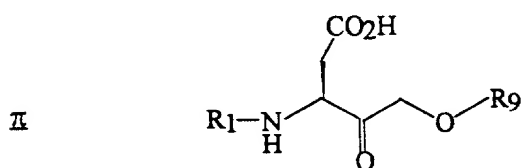
Preferred compounds of embodiment C of this invention are also those in which each A is independently selected from the group consisting of the  $\alpha$ -amino acids:

- alanine,
- histidine,
- lysine,
- phenylalanine,
- proline,
- tyrosine,
- valine,

leucine,  
isoleucine,  
glutamine,  
methionine,  
5 homoproline,  
3-(2-thienyl) alanine, and  
3-(3-thienyl) alanine.

The ICE inhibitors of another embodiment (D)  
of this invention are represented by the formula  $\pi$ :

10



wherein:

$R_1$  is  $R_5-(A)_p-$ ;

each  $T_1$  is independently selected from the group  
15 consisting of:

-CH=CH-,  
-O-,  
-S-,  
-SO-,  
20 -SO<sub>2</sub>-,  
-NR<sub>10</sub>-,  
-NR<sub>10</sub>-CO-,  
-CO-,  
-O-CO-,  
25 -CO-O-,  
-CO-NR<sub>10</sub>-,  
-O-CO-NR<sub>10</sub>-,  
-NR<sub>10</sub>-CO-O-,

-NR<sub>10</sub>-CO-NR<sub>10</sub>- ,  
 -SO<sub>2</sub>-NR<sub>10</sub>- ,  
 -NR<sub>10</sub>-SO<sub>2</sub>- ,            and  
 -NR<sub>10</sub>-SO<sub>2</sub>-NR<sub>10</sub>- ;

5     R<sub>5</sub> is selected from the group consisting of:

         -H,  
          -Ar<sub>1</sub>,  
          -CO-Ar<sub>1</sub>,  
          -SO<sub>2</sub>-Ar<sub>1</sub>,  
 10       -R<sub>9</sub>,  
          -CO-R<sub>9</sub>,  
          -CO-O-R<sub>9</sub>,  
          -SO<sub>2</sub>-R<sub>9</sub>,  
              /Ar<sub>1</sub>  
 15       -CO-N     \R<sub>10</sub>,  
              /Ar<sub>1</sub>  
          -SO<sub>2</sub>-N     \R<sub>10</sub>,  
 20       -CO-N     /R<sub>9</sub>  
              \R<sub>10</sub>,     and  
              /R<sub>9</sub>  
 25       -SO<sub>2</sub>-N     \R<sub>10</sub>;

each A is independently selected from the group  
 consisting of any α-amino acid;

p is 0, 1, 2, 3 or 4;

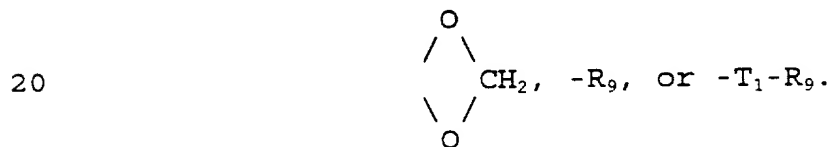
30       each R<sub>9</sub> is a C<sub>1-6</sub> straight or branched alkyl group  
 optionally singly or multiply substituted by -OH, -F,  
 or =O and optionally substituted with an Ar<sub>1</sub> group;

each R<sub>10</sub> is independently selected from the group

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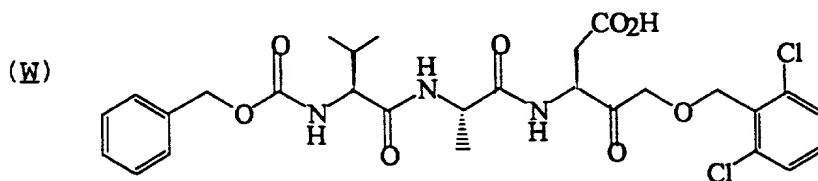
consisting of -H or a C<sub>1-6</sub> straight or branched alkyl group;

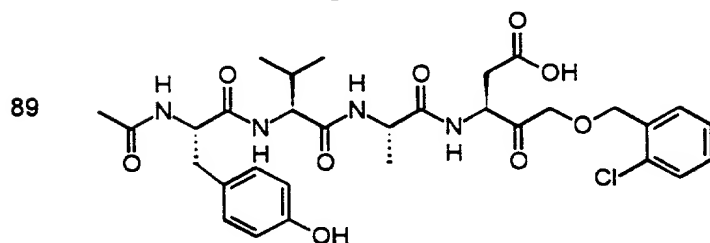
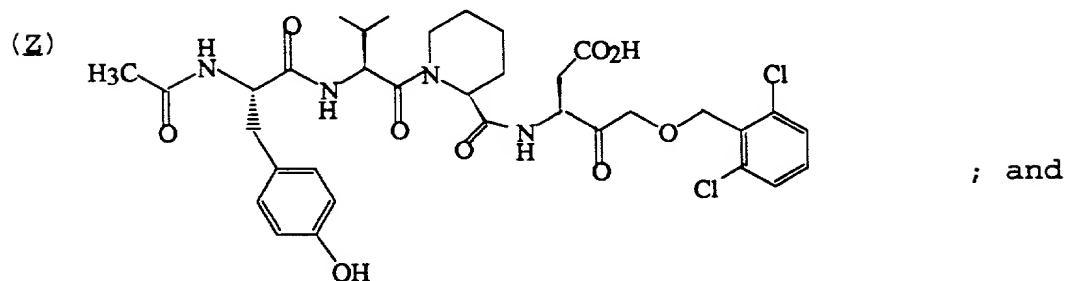
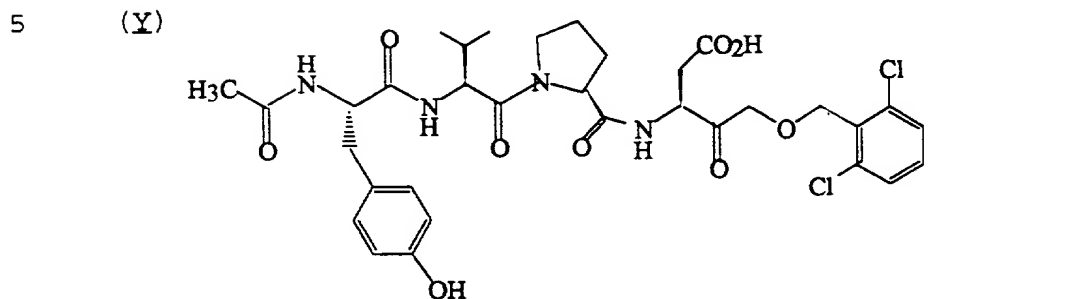
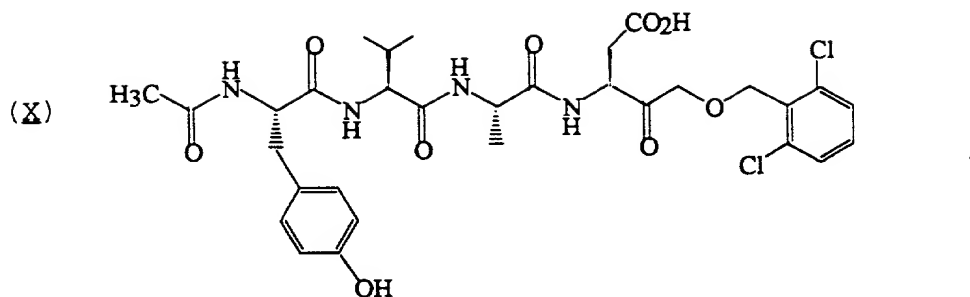
Ar<sub>1</sub> is a cyclic group independently selected from the set consisting of an aryl group which contains 6,  
 5 10, 12, or 14 carbon atoms and between 1 and 3 rings, a cycloalkyl group which contains between 3 and 15 carbon atoms and between 1 and 3 rings, said cycloalkyl group being optionally benzofused, and a heterocycle group containing between 5 and 15 ring atoms and between 1  
 10 and 3 rings, said heterocycle group containing at least one heteroatom group selected from -O-, -S-, -SO-, -SO<sub>2</sub>-, =N-, and -NH-, said heterocycle group optionally containing one or more double bonds, said heterocycle group optionally comprising one or more aromatic rings,  
 15 and said cyclic group optionally being singly or multiply substituted by -NH<sub>2</sub>, -CO<sub>2</sub>H, -Cl, -F, -Br, -I, -NO<sub>2</sub>, -CH<sub>3</sub>, =O, -OH, -perfluoro C<sub>1-3</sub> alkyl, or



Preferred compounds of embodiment D of this invention are those in which R<sub>9</sub> is a C<sub>1-4</sub> straight or  
 25 branched alkyl substituted with Ar<sub>1</sub> when Ar<sub>1</sub> is phenyl.

Preferred compounds of embodiment D of this invention include but are not limited to:





10

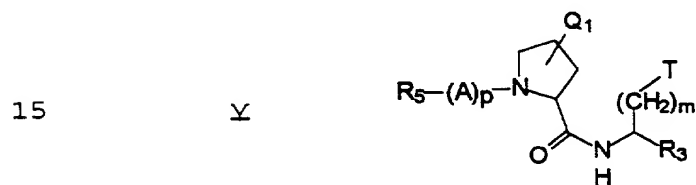
Preferred compounds of embodiment D of this invention are also those in which A is independently selected from the group consisting of the  $\alpha$ -amino acids:

15

alanine,  
histidine,

lysine,  
phenylalanine,  
proline,  
tyrosine,  
5 valine,  
leucine,  
isoleucine,  
glutamine,  
methionine,  
10 homoproline,  
3-(2-thienyl) alanine, and  
3-(3-thienyl) alanine.

The ICE inhibitors of another embodiment (E)  
of this invention are represented by formula  $\gamma$ :



wherein:

m is 0, 1, or 2;

20 T is  $-\text{CO}_2\text{H}$ , or any bioisosteric  
replacement for  $-\text{CO}_2\text{H}$ ,

R<sub>3</sub> is  
-CN,  
-COR<sub>13</sub>, or  
/R<sub>5</sub>  
25 -COCO-N  
    \R<sub>10</sub>,

R<sub>5</sub> is selected from the group consisting of:

- 5            -H,  
             -Ar<sub>1</sub>,  
             -CO-Ar<sub>1</sub>,  
             -SO<sub>2</sub>-Ar<sub>1</sub>,  
             -R<sub>9</sub>,  
             -CO-R<sub>9</sub>,  
             -CO-O-R<sub>9</sub>,  
             -SO<sub>2</sub>-R<sub>9</sub>,  
10            /Ar<sub>1</sub>  
             -CO-N \R<sub>10</sub>,  
                     /Ar<sub>1</sub>  
             -SO<sub>2</sub>-N \R<sub>10</sub>,  
15            /R<sub>9</sub>  
             -CO-N \R<sub>10</sub>,     and  
                     /R<sub>9</sub>  
20            -SO<sub>2</sub>-N \R<sub>10</sub>;

each A is independently selected from the group consisting of any α-amino acid;

p is 2 or 3;

- 25            each R<sub>9</sub> is a C<sub>1-6</sub> straight or branched alkyl group optionally singly or multiply substituted by -OH, -F, or =O and optionally substituted with one Ar<sub>1</sub> group;

each T<sub>1</sub> is independently selected from the group consisting of:

- 30            -CH=CH-,  
             -O-,  
             -S-,  
             -SO-,

5           -SO<sub>2</sub>-,  
          -NR<sub>10</sub>-,  
          -NR<sub>10</sub>-CO-,  
          -CO-,  
          -O-CO-,  
          -CO-O-,  
          -CO-NR<sub>10</sub>-,  
          -O-CO-NR<sub>10</sub>-,  
          -NR<sub>10</sub>-CO-O-,  
10          -NR<sub>10</sub>-CO-NR<sub>10</sub>-,  
          -SO<sub>2</sub>-NR<sub>10</sub>-,  
          -NR<sub>10</sub>-SO<sub>2</sub>-,           and  
          -NR<sub>10</sub>-SO<sub>2</sub>-NR<sub>10</sub>-;

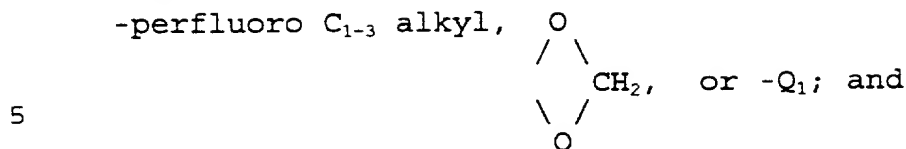
15           each R<sub>10</sub> is independently selected from the group  
consisting of -H or a -C<sub>1-6</sub> straight or branched alkyl  
group;

          each R<sub>13</sub> is independently selected from the group  
consisting of H, R<sub>9</sub>, Ar<sub>2</sub>, and CH<sub>2</sub>T<sub>1</sub>R<sub>9</sub>;

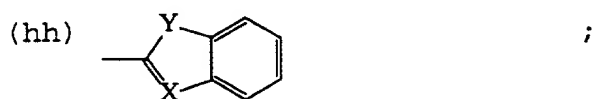
20           each Ar<sub>1</sub> is a cyclic group independently selected  
from the set consisting of an aryl group which contains  
6, 10, 12, or 14 carbon atoms and between 1 and 3  
rings, a cycloalkyl group which contains between 3 and  
15 carbon atoms and between 1 and 3 rings, said  
25          cycloalkyl group being optionally benzofused, and a  
heterocycle group containing between 5 and 15 ring  
atoms and between 1 and 3 rings, said heterocycle group  
containing at least one heteroatom group selected from  
-O-, -S-, -SO-, -SO<sub>2</sub>-, =N-, and -NH-, said heterocycle  
30          group optionally containing one or more double bonds,  
said heterocycle group optionally comprising one or  
more aromatic rings, and said cyclic group optionally  
being singly or multiply substituted by -NH<sub>2</sub>, -CO<sub>2</sub>H,



-Cl, -F, -Br, -I, -NO<sub>2</sub>, -CN, =O, -OH,  
-perfluoro C<sub>1-3</sub> alkyl,



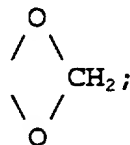
10 each Ar<sub>2</sub> is independently selected from the following group, in which any ring may optionally be singly or multiply substituted by -Q<sub>1</sub> and -Q<sub>2</sub>:



20 each Q<sub>1</sub> is independently selected from the group consisting of:

-Ar<sub>1</sub>  
-O-Ar<sub>1</sub>  
-R<sub>9</sub>,  
-T<sub>1</sub>-R<sub>9</sub>, and  
25 -(CH<sub>2</sub>)<sub>1,2,3</sub>-T<sub>1</sub>-R<sub>9</sub>;

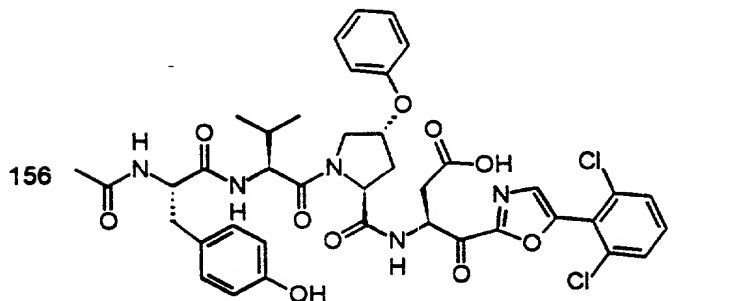
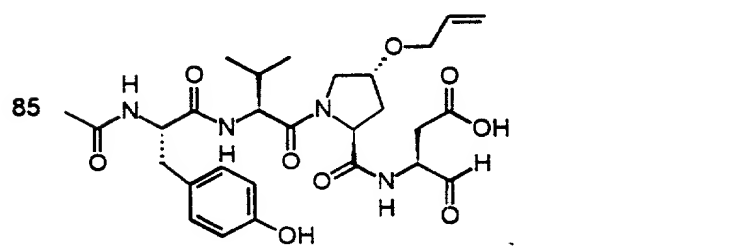
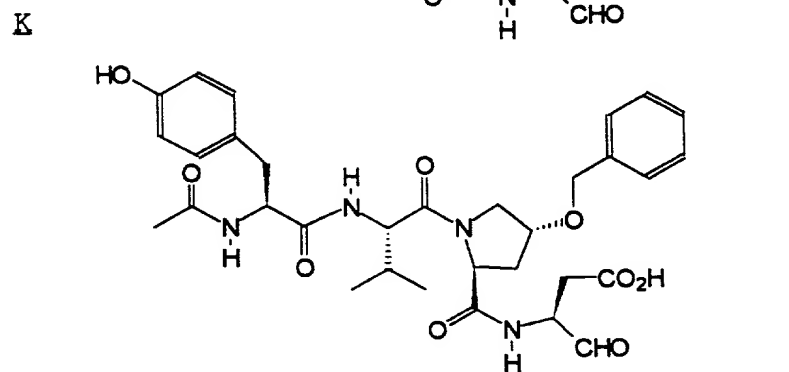
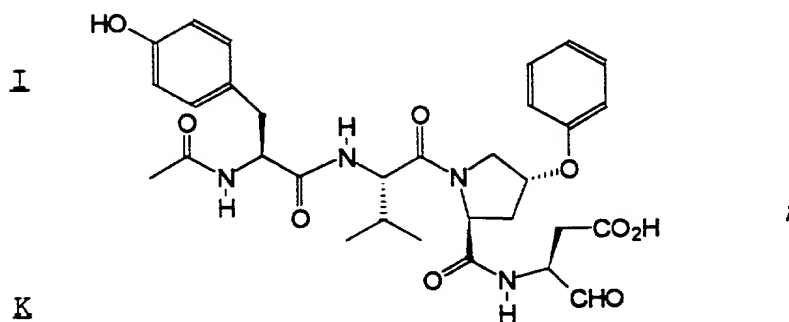
30 each Q<sub>2</sub> is independently selected from the group consisting of -OH, -NH<sub>2</sub>, -CO<sub>2</sub>H, -Cl, -F, -Br, -I, -NO<sub>2</sub>, -CN, -CF<sub>3</sub>, and



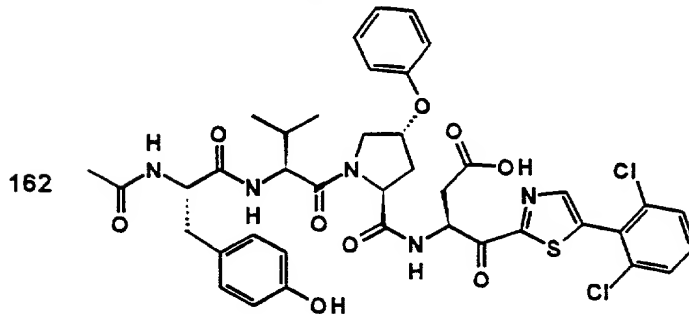
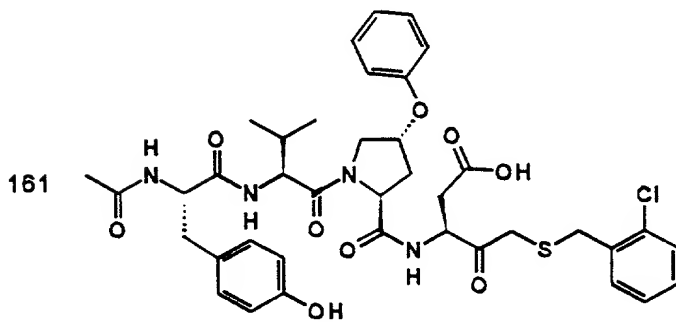
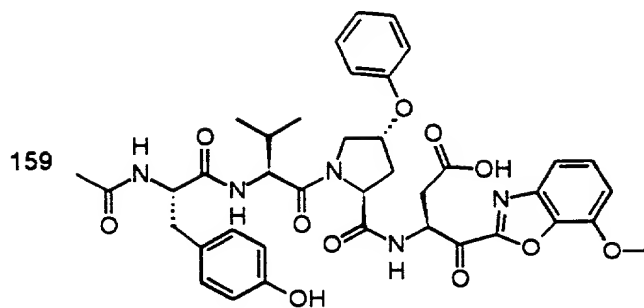
35 provided that when -Ar<sub>1</sub> is substituted with a Q<sub>1</sub>

group which comprises one or more additional  $-Ar_1$  groups, said additional  $-Ar_1$  groups are not substituted with  $Q_1$ .

Preferred compounds of embodiment E of this invention include but are not limited to:



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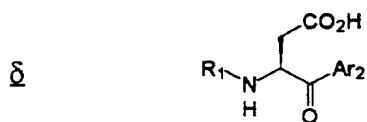


Preferred compounds of embodiment E of this invention are also those in which A is independently selected from the group consisting the  $\alpha$ -amino acids:

alanine,  
histidine,  
lysine,  
phenylalanine,  
proline,  
tyrosine,  
valine,  
leucine,

isoleucine,  
glutamine,  
methionine,  
homoproline,  
5 3-(2-thienyl) alanine, and  
3-(3-thienyl) alanine.

The ICE inhibitors of another embodiment (F)  
of this invention are represented by formula  $\delta$ :



10 wherein:

$\text{R}_1$  is  $\text{R}_5-(\text{A})_p$ ;

$\text{R}_5$  is selected from the group consisting of:

-H,  
- $\text{Ar}_1$ ,  
15 -CO- $\text{Ar}_1$ ,  
-SO<sub>2</sub>- $\text{Ar}_1$ ,  
- $\text{R}_9$ ,  
-CO- $\text{R}_9$ ,  
-CO-O- $\text{R}_9$ ,  
20 -SO<sub>2</sub>- $\text{R}_9$ ,  
-CO-N  $\begin{array}{l} / \text{Ar}_1 \\ \backslash \text{R}_{10} \end{array}$ ,  
-SO<sub>2</sub>-N  $\begin{array}{l} / \text{Ar}_1 \\ \backslash \text{R}_{10} \end{array}$ ,  
25 -CO-N  $\begin{array}{l} / \text{R}_9 \\ \backslash \text{R}_{10} \end{array}$ , and  
30 -SO<sub>2</sub>-N  $\begin{array}{l} / \text{R}_9 \\ \backslash \text{R}_{10} \end{array}$ ;

each A is independently selected from the group consisting of any  $\alpha$ -amino acid;

p is 0, 1, 2, 3 or 4;

5 each R<sub>9</sub> is a C<sub>1-6</sub> straight or branched alkyl group optionally singly or multiply substituted by -OH, -F, or =O and optionally substituted with one Ar<sub>1</sub> group;

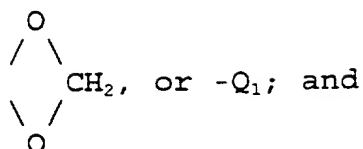
each R<sub>10</sub> is independently selected from the group consisting of -H or a C<sub>1-6</sub> straight or branched alkyl group;

10 each T<sub>1</sub> is independently selected from the group consisting of:

-CH=CH-,  
-O-,  
-S-,  
15 -SO-,

each Ar<sub>1</sub> is a cyclic group independently selected from the set consisting of an aryl group which contains 6, 10, 12, or 14 carbon atoms and between 1 and 3 rings, a cycloalkyl group which contains between 3 and 20 15 carbon atoms and between 1 and 3 rings, said cycloalkyl group being optionally benzofused, and a heterocycle group containing between 5 and 15 ring atoms and between 1 and 3 rings, said heterocycle group containing at least one heteroatom group selected from 25 -O-, -S-, -SO-, -SO<sub>2</sub>-, =N-, and -NH-, said heterocycle group optionally containing one or more double bonds, said heterocycle group optionally comprising one or more aromatic rings, and said cyclic group optionally being singly or multiply substituted by -NH<sub>2</sub>, -CO<sub>2</sub>H, 30 -Cl, -F, -Br, -I, -NO<sub>2</sub>, -CN, =O, -OH,

-perfluoro C<sub>1-3</sub> alkyl,

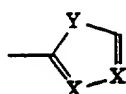


5

each Ar<sub>2</sub> is independently selected from the following group, in which any ring may optionally be singly or multiply substituted by -Q<sub>1</sub> and -Q<sub>2</sub>:

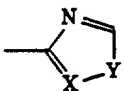
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(ii)



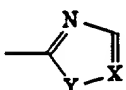
;

(jj)



; and

(kk)



15

;

each Q<sub>1</sub> is independently selected from the group consisting of:

-Ar<sub>1</sub>

-O-Ar<sub>1</sub>

20

-R<sub>9</sub>,

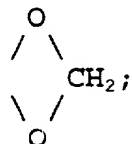
-T<sub>1</sub>-R<sub>9</sub>,

and

-(CH<sub>2</sub>)<sub>1,2,3</sub>-T<sub>1</sub>-R<sub>9</sub>;

each Q<sub>2</sub> is independently selected from the group consisting of -OH, -NH<sub>2</sub>, -CO<sub>2</sub>H, -Cl, -F, -Br, -I, -NO<sub>2</sub>, -CN, -CF<sub>3</sub>, and

25



30

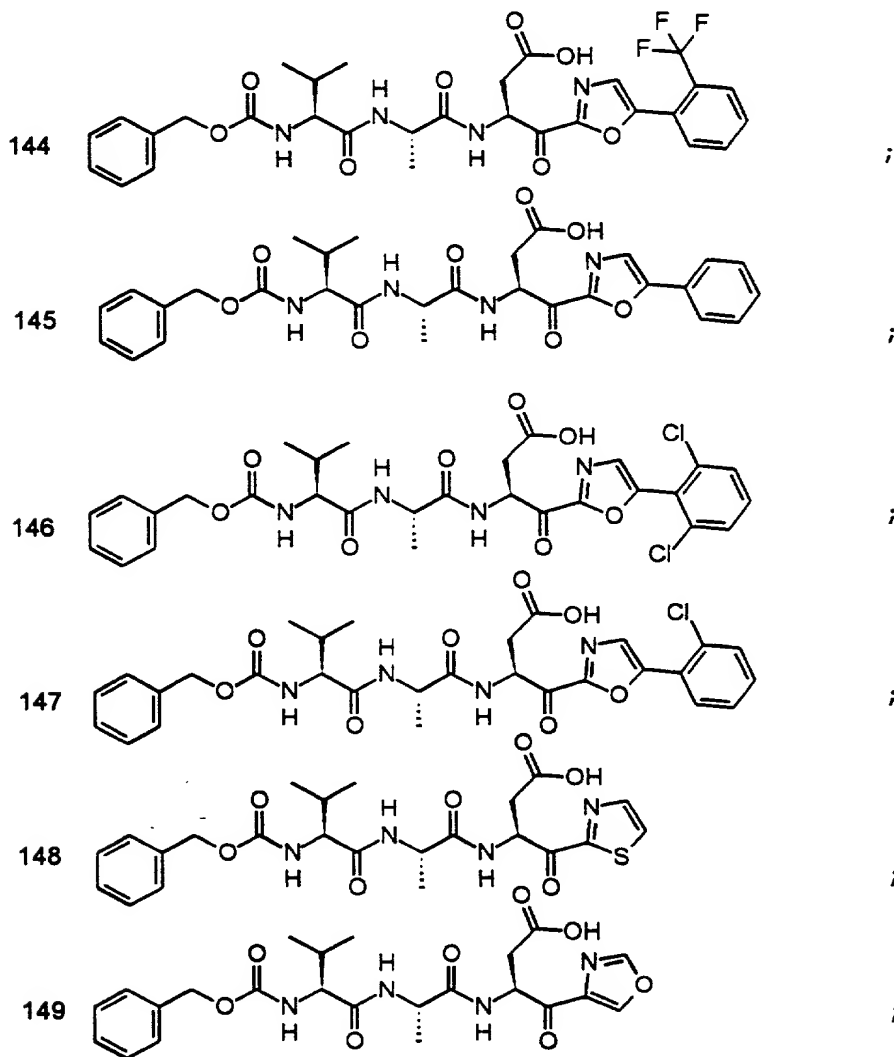
provided that when -Ar<sub>1</sub> is substituted with a Q<sub>1</sub> group which comprises one or more additional -Ar<sub>1</sub>

groups, said additional  $-\text{Ar}_1$  groups are not substituted with  $\text{Q}_1$ ;

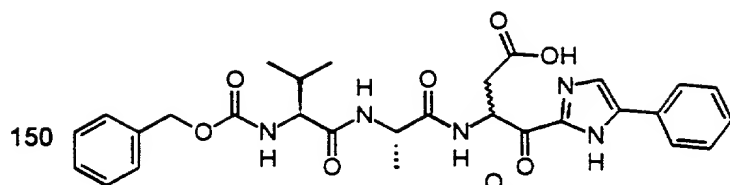
each X is independently selected from the group consisting of  $=\text{N}-$ , and  $=\text{CH}-$ ; and

5 each Y is independently selected from the group consisting of  $-\text{O}-$ ,  $-\text{S}-$ , and  $-\text{NH}$ .

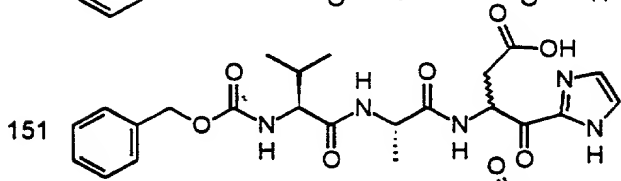
Preferred compounds of embodiment F of this invention include but are not limited to:



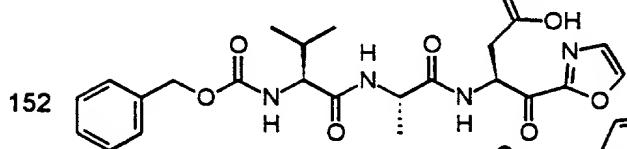
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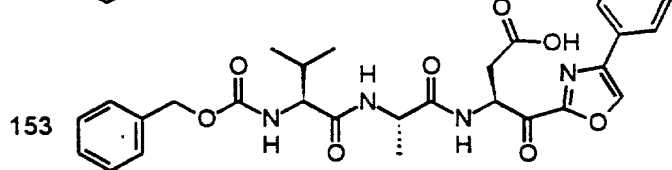
;



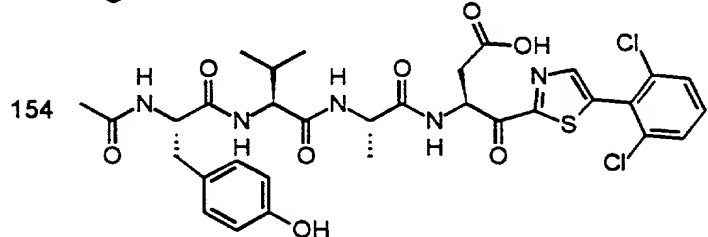
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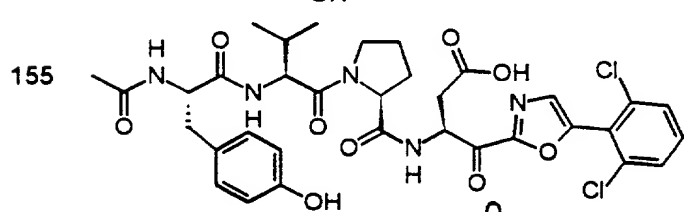
;



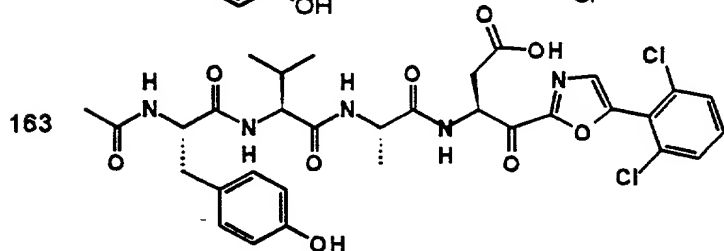
;



;



; and



.

Preferred compounds of embodiment F of this invention are also those in which A is independently selected from the group consisting the  $\alpha$ -amino acids: alanine,



histidine,  
lysine,  
phenylalanine,  
proline,  
5 tyrosine,  
valine,  
leucine,  
isoleucine,  
glutamine,  
10 methionine,  
homoproline,  
3-(2-thienyl) alanine, and  
3-(3-thienyl) alanine.

The compounds of this invention having a  
15 molecular weight of less than or equal to about 700  
Daltons, and more preferably between about 400 and 600  
Daltons, are preferred. These preferred compounds may  
be readily absorbed by the bloodstream of patients upon  
oral administration. This oral availability makes such  
20 compounds excellent agents for orally-administered  
treatment and prevention regimens against IL-1 mediated  
diseases.

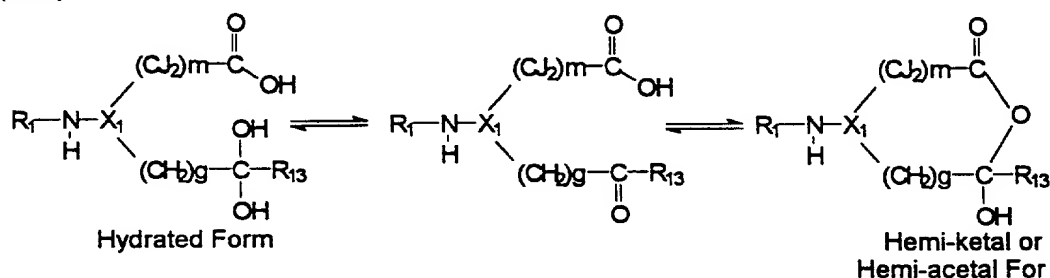
The ICE inhibitors of this invention may be  
synthesized using conventional techniques.  
25 Advantageously, these compounds are conveniently  
synthesized from readily available starting materials.

The compounds of this invention are among the  
most readily synthesized ICE inhibitors known.  
Previously described ICE inhibitors often contain four  
30 or more chiral centers and numerous peptide linkages.  
The relative ease with which the compounds of this  
invention can be synthesized represents an enormous  
advantage in the large scale production of these

compounds.

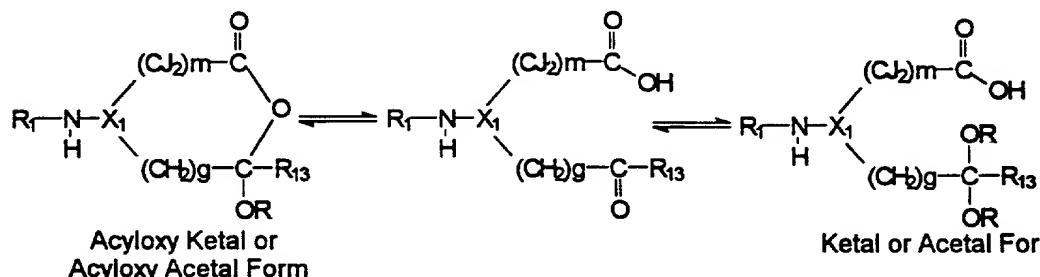
It should be understood that the compounds of this invention may exist in various equilibrium forms, depending on conditions including choice of solvent, pH, and others known to the practitioner skilled in the art. All such forms of these compounds are expressly included in the present invention. In particular, many of the compounds of this invention, especially those which contain aldehyde or ketone groups in R<sub>3</sub> and carboxylic acid groups in T, may take hemi-ketal (or hemi-acetal) or hydrated forms, as depicted below:

(EQ1)



Depending on the choice of solvent and other conditions known to the practitioner skilled in the art, compounds of this invention may also take acyloxy ketal, acyloxy acetal, ketal or acetal form:

(EQ2)



In addition, it should be understood that the equilibrium forms of the compounds of this invention may include tautomeric forms. All such forms of these

compounds are expressly included in the present invention.

It should be understood that the compounds of this invention may be modified by appropriate functionalities to enhance selective biological properties. Such modifications are known in the art and include those which increase biological penetration into a given biological system (e.g., blood, lymphatic system, central nervous system), increase oral availability, increase solubility to allow administration by injection, alter metabolism and alter rate of excretion. In addition, the compounds may be altered to pro-drug form such that the desired compound is created in the body of the patient as the result of the action of metabolic or other biochemical processes on the pro-drug. Some examples of pro-drug forms include ketal, acetal, oxime, and hydrazone forms of compounds which contain ketone or aldehyde groups, especially where they occur in the R<sub>3</sub> group of the compounds of this invention.

The compounds of this invention are excellent ligands for ICE. Accordingly, these compounds are capable of targeting and inhibiting events in IL-1 mediated diseases, such as the conversion of precursor IL-1 $\beta$  to mature IL-1 $\beta$  and, thus, the ultimate activity of that protein in inflammatory diseases, autoimmune diseases and neurodegenerative diseases. For example, the compounds of this invention inhibit the conversion of precursor IL-1 $\beta$  to mature IL-1 $\beta$  by inhibiting ICE. Because ICE is essential for the production of mature IL-1, inhibition of that enzyme effectively blocks initiation of IL-1 mediated physiological effects and symptoms, such as inflammation, by inhibiting the production of mature IL-1. Thus, by inhibiting IL-1 $\beta$  precursor activity, the compounds of this invention

effectively function as IL-1 inhibitors.

5 The compounds of this invention may be  
employed in a conventional manner for the treatment of  
diseases which are mediated by IL-1. Such methods of  
treatment, their dosage levels and requirements may be  
selected by those of ordinary skill in the art from  
available methods and techniques. For example, a  
compound of this invention may be combined with a  
pharmaceutically acceptable adjuvant for administration  
10 to a patient suffering from an IL-1 mediated disease in  
a pharmaceutically acceptable manner and in an amount  
effective to lessen the severity of that disease.

Alternatively, the compounds of this  
invention may be used in compositions and methods for  
15 treating or protecting individuals against IL-1  
mediated diseases over extended periods of time. The  
compounds may be employed in such compositions either  
alone or together with other compounds of this  
invention in a manner consistent with the conventional  
20 utilization of ICE inhibitors in pharmaceutical  
compositions. For example, a compound of this  
invention may be combined with pharmaceutically  
acceptable adjuvants conventionally employed in  
vaccines and administered in prophylactically effective  
25 amounts to protect individuals over an extended period  
time against IL-1 mediated diseases.

The compounds of this invention may also be  
co-administered with other ICE inhibitors to increase  
the effect of therapy or prophylaxis against various  
30 IL-1-mediated diseases.

In addition, the compounds of this invention  
may be used in combination either conventional anti-  
inflammatory agents or with matrix metalloprotease  
inhibitors, lipoxxygenase inhibitors and antagonists of  
35 cytokines other than IL-1 $\beta$ .

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or suspensions may also contain a long-chain alcohol diluent or dispersant such as Ph. Hely or a similar alcohol.

5           The pharmaceutical compositions of this invention may be orally administered in any orally acceptable dosage form including, but not limited to, capsules, tablets, and aqueous suspensions and solutions. In the case of tablets for oral use,  
10       carriers which are commonly used include lactose and corn starch. Lubricating agents, such as magnesium stearate, are also typically added. For oral administration in a capsule form, useful diluents include lactose and dried corn starch. When aqueous  
15       suspensions are administered orally, the active ingredient is combined with emulsifying and suspending agents. If desired, certain sweetening and/or flavoring and/or coloring agents may be added.

          The pharmaceutical compositions of this  
20       invention may also be administered in the form of suppositories for rectal administration. These compositions can be prepared by mixing a compound of this invention with a suitable non-irritating excipient which is solid at room temperature but liquid at the  
25       rectal temperature and therefore will melt in the rectum to release the active components. Such materials include, but are not limited to, cocoa butter, beeswax and polyethylene glycols.

          Topical administration of the pharmaceutical  
30       compositions of this invention is especially useful when the desired treatment involves areas or organs readily accessible by topical application. For application topically to the skin, the pharmaceutical composition should be formulated with a suitable  
35       ointment containing the active components suspended or

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5 scleroderma, chronic thyroiditis, Graves' disease,  
autoimmune gastritis, insulin-dependent diabetes  
mellitus, autoimmune hemolytic anemia, autoimmune  
neutropenia, thrombocytopenia, chronic active  
hepatitis, myasthenia gravis and multiple sclerosis.  
And target neurodegenerative diseases include, for  
example, amyotrophic lateral sclerosis, Alzheimer's  
disease, Parkinson's disease, and primary lateral  
sclerosis. The ICE inhibitors of this invention may  
10 also be used to promote wound healing. And the ICE  
inhibitors of this invention may be used to treat  
infectious diseases.

15 Although this invention focuses on the use of  
the compounds disclosed herein for preventing and  
treating IL-1-mediated diseases, the compounds of this  
invention can also be used as inhibitory agents for  
other cysteine proteases.

20 The compounds of this invention are also  
useful as commercial reagents which effectively bind to  
ICE or other cysteine proteases. As commercial  
reagents, the compounds of this invention, and their  
derivatives, may be used to block proteolysis of a  
target peptide or may be derivatized to bind to a  
stable resin as a tethered substrate for affinity  
25 chromatography applications. These and other uses  
which characterize commercial cystine protease  
inhibitors will be evident to those of ordinary skill  
in the art.

30 In order that this invention be more fully  
understood, the following examples are set forth.  
These examples are for the purpose of illustration only  
and are not to be construed as limiting the scope of  
the invention in any way.

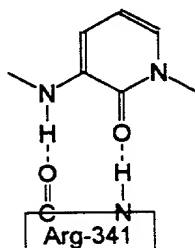
Example 1

The following example demonstrates a process of drug design which embodies the present invention:

Step 1) Pick 2 hydrogen bonding moieties of ICE,  
here, the backbone C=O and N-H of Arg-341.

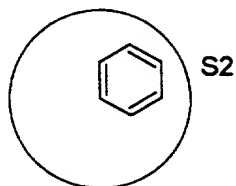
Step 2) Pick a scaffold, here, a pyridone derivative, and confirm that the hydrogen bonding moieties of the scaffold are capable of forming satisfactory hydrogen bonds with the hydrogen bonding moieties selected in step 1. This confirmation is performed by using molecular mechanics techniques to minimize the scaffold fragment in the context of the active site of ICE.

(Z1)



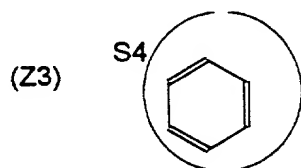
Step 3) Pick a hydrophobic pocket, here, S2, as next target and a hydrophobic moiety, here, benzene. Minimize the benzene group within the S2 pocket to assure that substantial hydrophobic overlap is obtained.

(Z2)

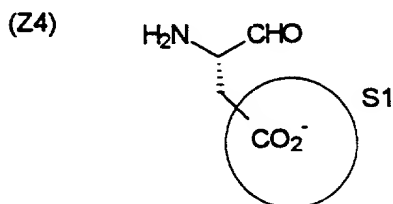


Step 4) Pick another hydrophobic pocket, here, S4, as the next target and a hydrophobic moiety,

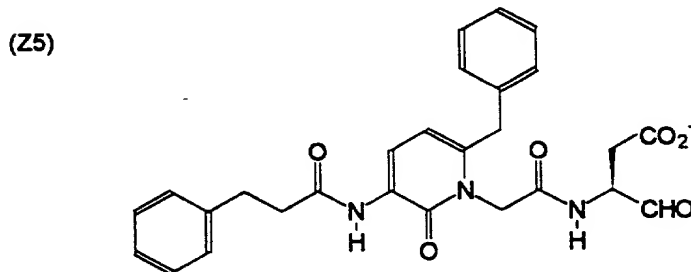
here, benzene. Minimize the benzene group within the S4 pocket to ensure that substantial hydrophobic overlap is obtained.



5 Step 5) Fill the S1 polar pocket with an electronegative moiety, here, a carboxylate sidechain provided by aspartic acid in which the C-terminus has been reduced to an aldehyde. Minimize to ensure that the carboxylate sidechain  
10 retains a favorable electrostatic interaction with the S1 polar pocket.



15 Step 6) Link the scaffold with the moieties from steps 3, 4, and 5, preferably using the minimum number of bonds consistent with a chemically reasonable structure. Minimize the entire composite molecule in the active site of ICE.



Step 7) Evaluate the energy of the molecule when it has the conformation necessary for binding to ICE. Then minimize and reevaluate the energy -- this is the free conformation energy. The strain energy for binding of the potential inhibitor to ICE is the difference between the free conformation energy and the bound conformation energy. The strain energy should be less than about 10 kcal/mol. In this case the bound conformation energy is -1.6 kcal/mol and the free conformation energy is -11.7 kcal/mol, for a strain energy of 10.1 kcal/mol.

Step 8) The inhibitor designed using the above steps has been made and has been shown to have a  $K_i$  of 150 nM.

#### Example 2

We obtained inhibition constants ( $K_i$ ) and  $IC_{50}$  values for several compounds of this invention using the three methods described below:

##### 20 1. Enzyme assay with UV-visible substrate

This assay is run using an Succinyl-Tyr-Val-Ala-Asp-pNitroanilide substrate. Synthesis of analogous substrates is described by L. A. Reiter (Int. J. Peptide Protein Res. 43, 87-96 (1994)). The assay mixture contains:

65  $\mu$ l buffer (10mM Tris, 1 mM DTT, 0.1% CHAPS @pH 8.1)  
10  $\mu$ l ICE (50 nM final concentration to give a rate of ~1mOD/min)  
5  $\mu$ l DMSO/Inhibitor mixture  
20  $\mu$ l 400 $\mu$ M Substrate (80  $\mu$ M final concentration)  
30 100 $\mu$ l total reaction volume

The visible ICE assay is run in a 96-well microtiter plate. Buffer, ICE and DMSO (if inhibitor

is present) are added to the wells in the order listed. The components are left to incubate at room temperature for 15 minutes starting at the time that all components are present in all wells. The microtiter plate reader is set to incubate at 37°C. After the 15 minute incubation, substrate is added directly to the wells and the reaction is monitored by following the release of the chromophore (pNA) at 405 - 603 nm at 37°C for 20 minutes. A linear fit of the data is performed and the rate is calculated in mOD/min. DMSO is only present during experiments involving inhibitors, buffer is used to make up the volume to 100  $\mu$ l in the other experiments.

## 2. Enzyme Assay with Fluorescent Substrate

This assay is run essentially according to Thornberry et al. (Nature 356: 768-774 (1992)), using substrate 17 referenced in that article. The substrate is: Acetyl-Tyr-Val-Ala-Asp-amino-4-methylcoumarin (AMC). The following components are mixed:

65  $\mu$ l buffer (10mM Tris, 1mM DTT, 0.1% CHAPS @pH8.1)  
10  $\mu$ l ICE (2 - 10 nM final concentration)  
5  $\mu$ l DMSO/inhibitor solution  
20  $\mu$ l 150  $\mu$ M Substrate (30  $\mu$ M final)  
100  $\mu$ l total reaction volume

The assay is run in a 96 well microtiter plate. Buffer and ICE are added to the wells. The components are left to incubate at 37°C for 15 minutes in a temperature-controlled wellplate. After the 15 minute incubation, the reaction is started by adding substrate directly to the wells and the reaction is monitored @37°C for 30 minutes by following the release of the AMC fluorophore using an excitation wavelength for 380 nm and an emission wavelength of 460 nm. A linear fit of the data for each well is performed and a

rate is determined in fluorescence units per second.

For determination of enzyme inhibition constants ( $K_i$ ) or the mode of inhibition (competitive, uncompetitive or noncompetitive), the rate data  
5 determined in the enzyme assays at varying inhibitor concentrations are computer-fit to standard enzyme kinetic equations (see I. H. Segel, Enzyme Kinetics, Wiley-Interscience, 1975).

### 3. Cell assay

10 IL-1 $\beta$  Assay with a Mixed Population of Human Peripheral Blood Mononuclear Cells (PBMC)  
or Enriched Adherent Mononuclear Cells

Processing of pre-IL-1 $\beta$  by ICE can be measured in cell culture using a variety of cell  
15 sources. Human PBMC obtained from healthy donors provides a mixed population of lymphocyte subtypes and mononuclear cells that produce a spectrum of interleukins and cytokines in response to many classes of physiological stimulators. Adherent mononuclear  
20 cells from PBMC provides an enriched source of normal monocytes for selective studies of cytokine production by activated cells.

#### Experimental Procedure:

An initial dilution series of test compound  
25 in DMSO or ethanol is prepared, with a subsequent dilution into RPMI-10% FBS media (containing 2 mM L-glutamine, 10 mM HEPES, 50 U and 50 ug/ml pen/strep) respectively to yield drugs at 4x the final test concentration containing 0.4% DMSO or 0.4% ethanol.  
30 The final concentration of DMSO is 0.1% for all drug dilutions. A concentration titration which brackets the apparent  $K_i$  for a test compound determined in an ICE inhibition assay is generally used for the primary compound screen.

35 We generally test 5-6 compound dilutions and

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have performed the cellular component of the assay in duplicate, with duplicate ELISA determinations on each cell culture supernatant.

PBMC Isolation and IL-1 Assay:

5           Buffy coat cells isolated from one pint human blood (yielding 40-45 ml final volume plasma plus cells) are diluted with media to 80 ml and LeukoPREP separation tubes (Becton Dickinson) are each overlaid with 10 ml of cell suspension. After 15 min  
10           centrifugation at 1500-1800 xg, the plasma/media layer is aspirated and then the mononuclear cell layer is collected with a Pasteur pipette and transferred to a 15 ml conical centrifuge tube (Corning). Media is added to bring the volume to 15 ml, gently mix the  
15           cells by inversion and centrifuge at 300 xg for 15 min. Resuspend the PBMC pellet in a small volume of media, count cells and adjust to  $6 \times 10^6$  cells/ml.

          For the cellular assay, add 1.0 ml of the cell suspension to each well of a 24-well flat bottom  
20           tissue culture plate (Corning), 0.5 ml test compound dilution and 0.5 ml LPS solution (Sigma #L-3012; 20 ng/ml solution prepared in complete RPMI media; final LPS concentration 5 ng/ml). The 0.5 ml additions of test compound and LPS are usually sufficient to mix the  
25           contents of the wells. Three control mixtures are run per experiment, with either LPS alone, solvent vehicle control, and/or additional media to adjust the final culture volume to 2.0 ml. The cell cultures are incubated for 16-18 hr at 37°C in the presence of 5%  
30           CO<sub>2</sub>.

          At the end of the incubation period, cells are harvested and transferred to 15 ml conical centrifuge tubes. After centrifugation for 10 min at 200 xg, supernatants are harvested and transferred to  
35           1.5 ml Eppendorf tubes. It may be noted that the cell

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5 Isolation of Adherent Mononuclear cells:

ELISA:

The inhibitory potency of the compounds can be represented by an  $IC_{50}$  value, which is the concentration of inhibitor at which 50% of mature IL-1 $\beta$  is detected in the supernatant as compared to the positive controls.

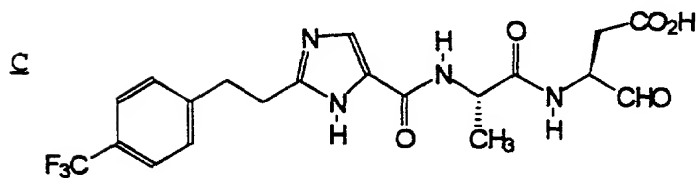
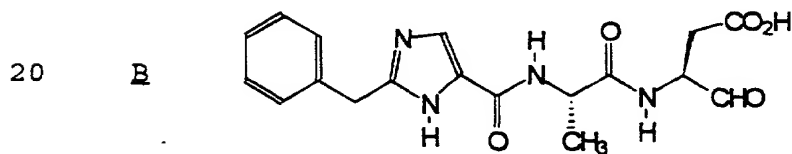
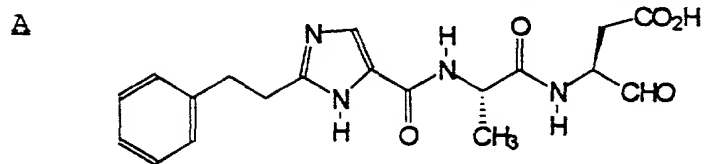
The following  $K_i$  and  $IC_{50}$  values were determined for compounds A through N using the indicated assays. Structures for compounds A through N follow this table.

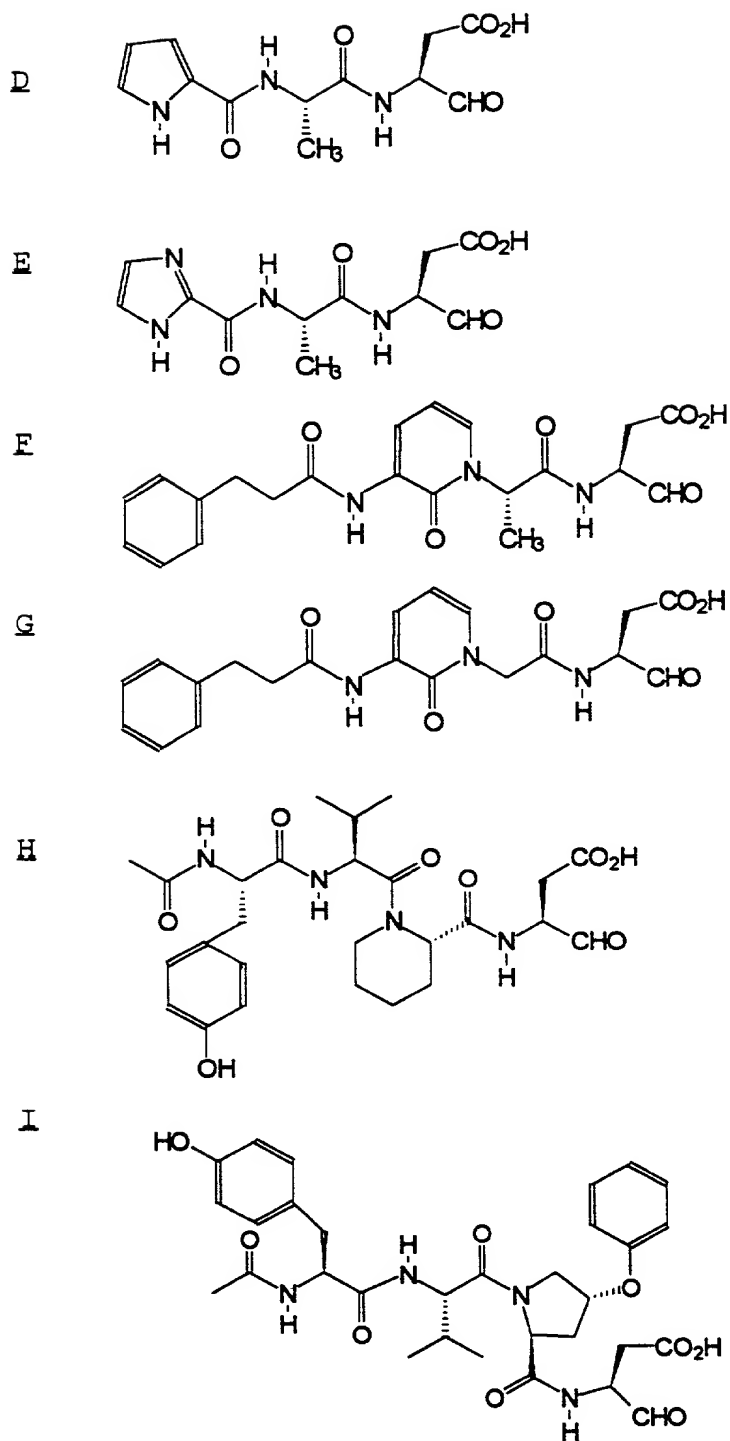


Compound  $K_i$  ( $\mu\text{M}$ ), by indicated assay:

		<u>UV-visible</u> $K_i$ ( $\mu\text{M}$ )	<u>Fluorescence</u> $K_i$ ( $\mu\text{M}$ )	<u>Cell</u> $\text{IC}_{50}$ ( $\mu\text{M}$ )
5	A	5.5		25.0
	B	8.6		20.0
	C	10		>30
	D	4.7		
	E	3.2		
10	F	0.15		2 - 4
	G	4.8		
	H	0.023	0.0047	6 - 11
	I	0.0072	0.0052	2.6
	J	0.012	0.0039	5 - 7
15	K	0.010	0.002	2 - 11
	L	0.014		
	M	0.15		
	N	0.95		

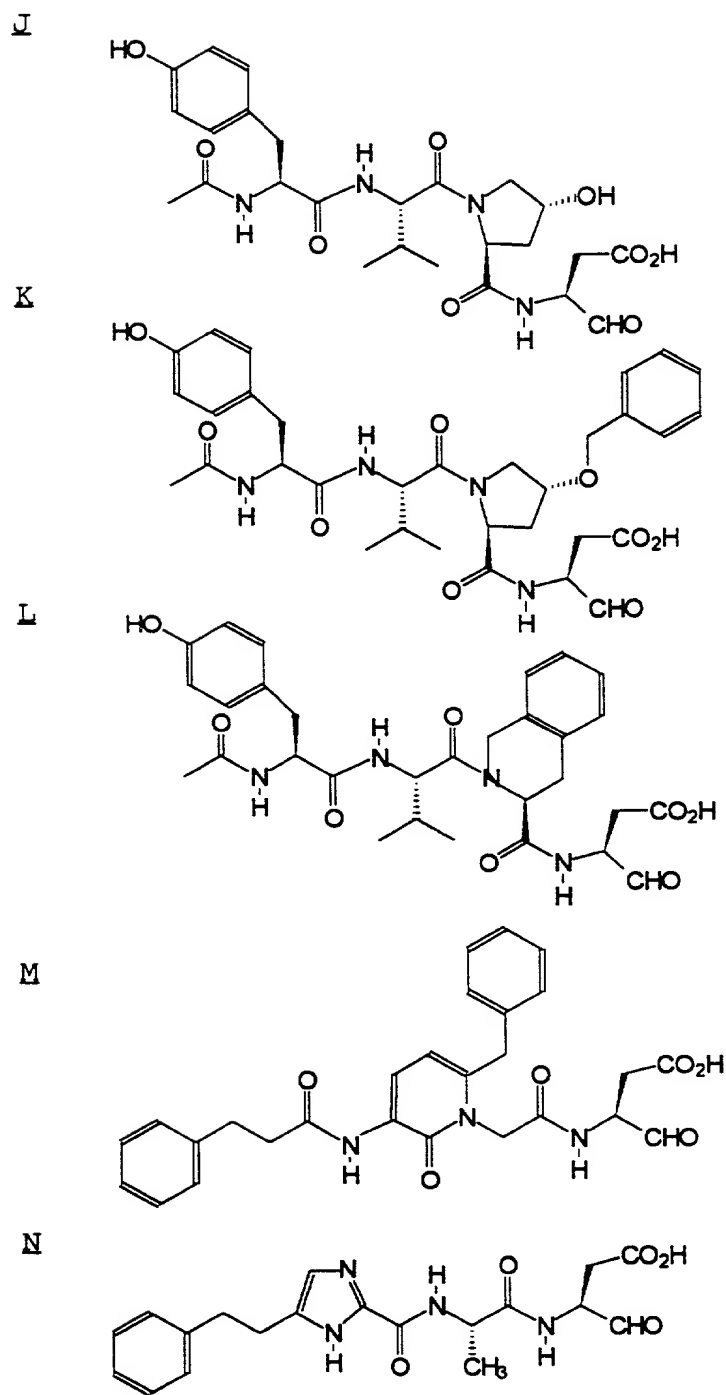
Structures of compounds A through N:





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Example 3

Compounds of Example 2 were synthesized as follows:

5     H. N-(N-Acetyl-tyrosinyl-valinyl-pipecolyl)-3-amino-4-oxobutanoic acid.

Step A.     N-(N-tert-Butoxycarbonylpipecolyl)-4-amino-5-benzyloxy-2-oxotetrahydrofuran.

10     Reaction of N-tert-butoxycarbonylpipecolic acid (460 mg, 2.0 mmol) and N-allyloxycarbonyl-4-amino-5-benzyloxy-2-oxotetrahydrofuran (530 mg, 1.82 mmol) was carried out by a method analogous to that reported by Chapman (Bioorg. & Med. Chem. Lett. 1992, 2, 613-618.) to give 654 mg of the title compound.

15     <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub> (existing as rotamers)) δ 7.35 (m, 5H), 6.88 (br. s, 1H), 4.9-4.45(m, 4H), 3.95 (br. m, 2H), 3.06 (m, 1H), 2.9 (m, 1H), 2.7 (br. m, 1H), 2.45 (m, 1H), 2.2 (m, 1H), 1.7-1.5 (m, 3H), 1.45 (two s, 9H).

20     Step B.     N-Pipecolyl-4-amino-5-benzyloxy-2-oxotetrahydrofuran.

25     N-(N-tert-Butoxycarbonylpipecolyl)-4-amino-5-benzyloxy-2-oxo-tetrahydrofuran (654 mg) was dissolved in 15 ml of 25% trifluoroacetic acid in dichloromethane and stirred at room temperature. The mixture was concentrated to give a gummy residue. The residue was dissolved in dichloromethane and washed with 10% sodium bicarbonate. The organic layer was dried over anhydrous sodium sulfate, filtered, and concentrated to give 422 mg of the title compound as a beige solid.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>) δ 7.38 (m, 5H), 7.15 (d, 1H), 5.55 (d, 1H), 4.95-4.8 (m, 1H), 4.78 (m, 1H), 4.65 (d, 1H), 4.45 (m, 1H), 3.2 (m, 0.5H), 3.05 (m, 0.5H), 2.95 (m, 0.5H), 2.85 (m, 0.5H), 2.65 (m, 1H), 2.55-2.38 (m, 1H), 1.95 (m, 1H), 1.8 (m, 1H), 1.6 (m, 2H), 1.38 (m, 2H).

Step C. N-(N-Acetyl-tyrosinyl-valinyl-pipecolyl)-4-amino-5-benzyloxy-2-oxotetrahydrofuran.

N-Acetyl-tyrosinyl-valine (464 mg, 1.44 mmol) and N-Pipecolyl-4-amino-5-benzyloxy-2-oxotetrahydrofuran (412 mg, 1.3 mmol) were dissolved in 5 ml each of dimethylformamide and dichloromethane and cooled to 0°C. To the cooled solution was added 1-hydroxybenzotriazole (HOBT; 210 mg, 1.56 mmol) followed by the addition of 1-(3-dimethylaminopropyl)-3-ethyl carbodiimide hydrochloride (EDC; 326 mg, 1.7 mmol). After stirring for 18 hours, the mixture was diluted with ethyl acetate and washed with water, 10% sodium hydrogen sulfate, 10% sodium bicarbonate, and water. The organic layer was concentrated to give a crude solid that was purified by flash chromatography (SiO<sub>2</sub>) eluting with 94:6:1 (dichloromethane:isopropanol:pyridine) to give 370 mg of the title compound.

<sup>1</sup>H NMR (500 MHz, CD<sub>3</sub>OD (existing as diastereomers as well as rotamers)) δ 7.35 (m, 5H), 7.05 (m, 2H), 6.68 (m, 2H), 5.65 & 5.25 (m, 1H), 4.9-3.95 (m, 8H), 3.4-2.6 (m, 4H), 2.5-2.1 (m, 1H), 1.98 (s, 1H), 1.9 (s, 1H), 1.85 (s, 1H), 1.8-1.6 (m, 2H), 1.55-1.3 (m, 4H), 0.95-0.85 (m, 6H).

Step D. N-(N-Acetyl-tyrosinyl-valinyl-pipecolyl)-3-amino-4-oxobutanoic acid.

To a solution of 100 mg of N-(N-Acetyl-tyrosinyl-valinyl-pipecolyl)-4-amino-5-benzyloxy-2-oxotetrahydrofuran in 10 ml of methanol was added 60 mg of Pd(OH)<sub>2</sub> on carbon and the mixture placed under an atmosphere of hydrogen via a balloon. The mixture was filtered through Celite and concentrated providing a white solid. This crude solid was dissolved in 2 ml of methanol and triturated with diethyl ether affording 26 mg of the title compound.

<sup>1</sup>H NMR (500 MHz, CD<sub>3</sub>OD (existing as diastereomers as well as rotamers)) δ 7.1 (m, 2H), 6.7 (m, 2H), 5.2 (br. m, 1H), 4.8-3.6 (m, 6H), 3.2-2.5 (m, 4H), 2.5-2.1 (m, 1H), 1.95 (three s, 3H), 1.9-1.3 (m, 6H), 1.1-0.7 (m, 6H).

The following compounds were prepared by a method analogous to that reported for H:

J. N-[N-Acetyl-tyrosinyl-valinyl-(4-hydroxyprolinyl)]-3-amino-4-oxobutanoic acid

Substitute N-tert-butoxycarbonyl-4-benzyloxyproline for N-tert-butoxycarbonylpipecolic acid.

L. N-[2-(N-Acetyl-tyrosinyl-valinyl)-(S)-1,2,3,4-tetrahydroisoquinoline-3-carbonyl]-3-amino-oxobutanoic acid

Substitute (S)-N-tert-butoxycarbonyl-1,2,3,4-tetrahydroisoquinoline-3-carboxylic acid for N-tert-butoxycarbonylpipecolic acid.

I. N-(N-Acetyl-tyrosinyl-valinyl-(4-phenoxyprolinyl))-3-amino-4-oxobutanoic acid.

Step A. N-tert-Butoxycarbonyl-4-phenoxyproline methyl ester.

5 To a cooled solution (0° C) of N-tert-butoxy-  
cis-4-hydroxyproline (2.0 g, 8.15 mmol), phenol (0.77  
g, 8.15 mmol), and triphenylphosphine (2.14 g, 8.15  
mmol) in 20 ml of tetrahydrofuran was added diethyl  
10 azodicarboxylate (1.4 ml, 9 mmol) dropwise over 30  
minutes. The reaction was stirred at room temperature  
for 16 hrs. then concentrated to give a viscous  
residue. The crude residue was purified by flash  
chromatography (SiO<sub>2</sub>) eluting with 3:7 (ethyl  
acetate:hexane) to give 1.89 g of the title compound.

15 <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>) δ 7.3 (m, 2H), 6.95 (m,  
1H), 6.85 (d, 2H), 4.9 (m br., 1H), 4.55-4.15 (m, 2H),  
3.88-3.65 (m, 1H), 3.70 (s, 3H), 2.58 (m, 1H), 2.22 (m,  
1H), 1.4 (3 x s, 9H).

20 Step B. 4-Phenoxyproline methyl ester  
hydrochloride.

To a cooled solution (ice bath) of N-tert-  
Butoxycarbonyl-4-phenoxyproline methyl ester (0.6 g) in  
20 ml of ethyl acetate was bubbled anhydrous hydrogen  
chloride until saturated. The mixture was warmed to  
25 room temperature and stirred for 3 hrs. then  
concentrated to give 480 mg of the title compound.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>) δ 7.22 (m, 2H), 6.95 (m 1  
H), 6.83 (m, 2H), 5.1 (br., 1H), 4.6 (br. m, 1H), 4.06

(br. m, 1H), 3.75 (s, 3H), 3.55 (br. m, 1H), 2.58 (m, 2H).

Step C. N-Acetyl-tyrosinyl-valinyl-(4-phenoxy)proline methyl ester.

5 N-Acetyl-tyrosinyl-valine (0.524 g, 1.63 mmol) and 4-phenoxyproline methyl ester (0.381 g, 1.48 mmol) were dissolved in 4 ml each of dimethylformamide and dichloromethane and cooled to 0° C. To the cooled solution was added diisopropylethylamine (258 ul, 1.86  
10 mmol), HOBT (0.24 g, 1.78 mmol), and EDC (0.37 g, 1.92 mmol) and the reaction was stirred for 18 hrs. The mixture was diluted with 400 ml of ethyl acetate and washed with water, 10% sodium hydrogen sulfate, 10% sodium bicarbonate, and water. The organic layer was  
15 concentrated to give a residue that was purified by flash chromatography (SiO<sub>2</sub>) eluting with 94:6:1 (CH<sub>2</sub>Cl<sub>2</sub>:i-PrOH:Pyridine) to afford 360 mg of the title compound.

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub> (existing as rotamers)) δ  
20 7.3 (m, 2H), 7.05 (m, 1H), 6.95 (d, 2H), 6.9-6.2 (4 x d, 4H), 5.05 (br. s, 1H), 4.7-3.94 (m, 5H), 2.93 (m, 1H), 2.82 (m, 1H), 2.65 (m, 1H), 2.2 (m, 1H), 2.05 (m, 1H), 1.95 (s, 3H), 1.86, (m, 1H), 0.98 (d, 3H), 0.88 (d, 3H).

25 Step D. N-Acetyl-tyrosinyl-valinyl-(4-phenoxy)proline.

Lithium hydroxide (57 mg, 1.37 mmol) was added to a solution of N-Acetyl-tyrosinyl-valinyl-(4-phenoxy)proline methyl ester (360 mg, 0.685 mmol)  
30 dissolved in 8 ml of tetrahydrofuran/water (1:1) and



stirred at room temperature for 1 hour. The mixture was acidified with 10% hydrochloric acid giving a white precipitate that was collected to give 175 mg of the title compound.

5  $^1\text{H}$  NMR (500 MHz, DMSO- $d_6$ )  $\delta$  9.2 (br. s, 1H),  
8.05-7.95 (m, 2H), 7.3 (m, 1H), 7.0-6.9 (m, 4H), 6.65  
(d, 2H), 4.42 (m, 1H), 4.35 (m, 1H), 4.05-3.95 (m, 2H),  
3.3 (br. s, 2H), 2.75 (m, 1H), 2.55-2.38 (m, 2H), 2.2  
(m, 1H), 2.0 (m, 1H), 1.7 (s, 3H), 0.95 (d, 3H), 0.85  
10 (d, 3H).

Step E. N-[N-Acetyl-tyrosinyl-valinyl-(4-  
phenoxy)prolinyl]-4-amino-5-benzyloxy-2-  
oxotetrahydrofuran.

15 The title compound was prepared by the method  
reported for compound H, step A, by reaction of N-  
acetyl-tyrosinyl-valinyl-(4-phenoxy)proline and N-  
allyloxycarbonyl-4-amino-5-benzyloxytetrahydrofuran.

20  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ , (existing as a 1:1  
diastereomer mixture of the hemiacetal))  $\delta$  7.8-6.3 (m,  
17H), 5.6 (d, 1H), 5.1-4.15 (m, 5H), 4.15-3.75 (m, 2H),  
2.95-2.15 (m, 5H), 2.15-1.95 (m, 1H), 1.9-1.85 (2 x s,  
3H), 1.1-0.75 (m, 6H).

25 Step F. N-[N-Acetyl-tyrosinyl-valinyl-(4-  
phenoxy)prolinyl]-3-amino-4-oxobutanoic  
acid.

The title compound was prepared by the  
hydrogenolysis procedure reported for compound H,  
step D.

<sup>1</sup>H NMR (500 MHz, CD<sub>3</sub>OD (existing as a 1:1 diastereomer mixture of the hemiacetal)) δ 7.25 (m, 2H), 7.10-6.85 (m, 5H), 6.65 (d, 2H), 5.1 (br. m, 1H), 4.65-4.05 (m, 5H), 4.0-3.40 (m, 2H), 2.95-2.35 (m, 5H), 2.25 (m, 1H), 2.05 (m, 1H), 1.85 (s, 3H), 1.0 (d, 3H), 0.95 (d, 3H).

K. N-[N-Acetyl-tyrosinyl-valinyl-(4-benzyloxy)prolinyl]-3-amino-4-oxobutanoic acid.

Step A. N-(N-Allyloxycarbonyl-4-benzyloxyprolinyl)-3-amino-4-oxobutanoic acid tert-butyl ester semicarbazone.

The title compound was prepared by the reaction of N-allyloxycarbonyl-4-benzyloxyproline and 3-amino-4-oxobutanoic acid tert-butyl ester semicarbazone (T.L. Graybill et. al., Abstracts of papers, 206th National Meeting of the American Chemical Society, Abstract MEDI-235. Chicago, IL. (1993)) under similar peptide coupling conditions as reported above (compound H; Step C).

<sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>) δ 9.05 (br. s, 1H), 7.85 (br. m, 1H), 7.4-7.2 (m, 5H), 7.15 (br. s, 1H), 6.55 (br. s, 1H), 5.9 (m, 1H), 5.1-4.9 (br. m, 2H), 4.65-4.4 (m, 4H), 4.2 (br. m, 1H), 3.75-3.5 (m, 2H), 2.75-2.55 (m, 2H), 2.5 (br. m, 1H), 2.25 (br. m, 1H) 1.4 (s, 9H).

Step B. N-(N-Acetyl-tyrosinyl-valinyl-(4-benzyloxyprolinyl))-3-amino-4-oxobutanoic acid tert-butyl ester semicarbazone.

The title compound was prepared by reaction of N-acetyl-tyrosinyl-valine and N-(N-allyloxycarbonyl-4-

benzyloxyprolinyl)-3-amino-4-oxobutanoic acid tert-butyl ester semicarbazone by reaction conditions reported for compound H, step A.

<sup>1</sup>H NMR (500MHz, CD<sub>3</sub>OD) δ 7.35-7.2 (m, 6H), 7.0 (d, 2H), 6.65(d, 2H), 4.85 (m, 1H), 4.6-4.45 (m, 4H), 4.3 (br. m, 1H), 4.15 (m, 1H), 3.7 (m, 1H), 2.95 (m, 1H), 2.75-2.6 (m, 3H), 2.35 (m, 1H), 2.1 (m, 1H), 1.9 (s, 3H), 1.4 (s, 9H), 0.95 (d, 3H), 0.90 (s, 3H).

Step C. N-(N-Acetyl-tyrosinyl-valinyl-(4-benzyloxyprolinyl))-3-amino-4oxobutanoic acid.

N-(N-Acetyl-tyrosinyl-valinyl-(4-benzyloxyprolinyl))-3-amino-4-oxobutanoic acid tert-butyl ester semicarbazone (270 mg) was dissolved into 10 ml of 25% trifluoroacetic acid in dichloromethane and stirred at room temperature for 3 hours. The mixture was concentrated to give a solid residue. The residue was dissolved into a 10 ml mixture of methanol:acetic acid:37% formaldehyde (3:1:1) and stirred at room temperature for 1 hour. The mixture was concentrated and the resulting residue purified by flash chromatography (SiO<sub>2</sub>) eluting with dichloromethane/methanol/formic acid (100:5:0.5) to give 37 mg of the title compound.

<sup>1</sup>H NMR (500 MHz, CD<sub>3</sub>OD (existing as a 1:1 mixture of diastereomers of the hemiacetal)) δ 7.4-7.25 (m, 5H), 7.0 (d, 2H), 6.65 (d, 2H), 4.65-4.05 (m, 7H), 3.75-3.4 (m, 2H), 3.05-2.3 (m, 5H), 2.2-1.95 (m, 2H), 1.90 (s, 3H), 1.0 (d, 3H), 0.95 (d, 3H).

Example 4

We obtained inhibition constants ( $K_i$ ) and  $IC_{50}$  values for several compounds of this invention using enzyme assays with UV-visible substrate and cell assays as described in Example 2. The following  $K_i$  and  $IC_{50}$  values were determined for compounds 7a, 7b, 20a-d, 21c-f, 22e, 25, 28, 33a-c, 36a, 36b, 39, 43, 47a, 47b, 54a-l, 63, 69a, 69b, 84a and 84b using the indicated assays. Corresponding lettered compound designations are indicated parenthetically. The compound structures are shown in Examples 2 and 5.

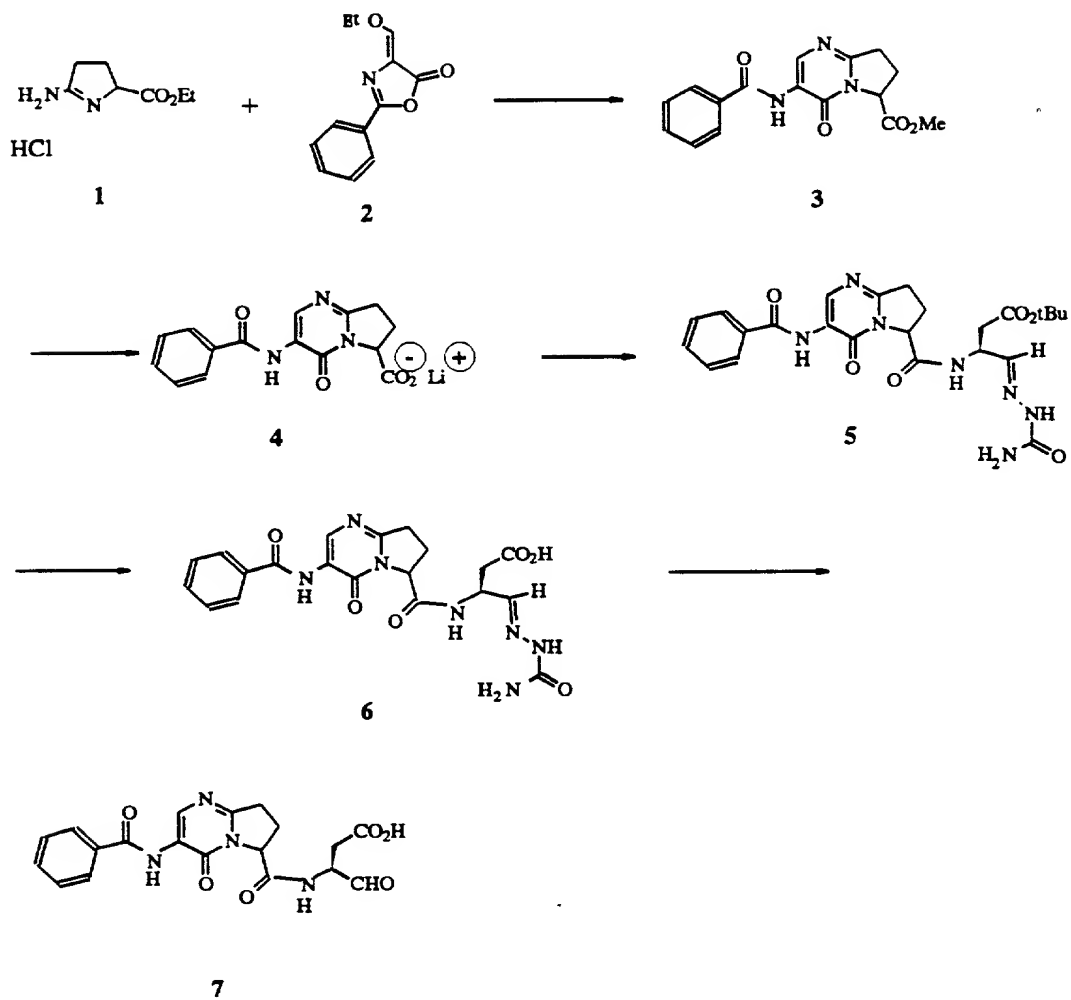
	<u>Compound</u>	<u>Assay</u>	
		<u>UV-visible</u> $K_i$ ( $\mu$ M)	<u>Cell</u> $IC_{50}$ ( $\mu$ M)
15	7a	35	
	7b	1.2	
	20a (= E)	3.2	
	20b	0.85	16.4
	20c (= N)	0.95	
20	20d	0.1	6.2
	21c	0.64	
	21d	0.24	4.8
	21e	0.22	2.9
	21f	0.17	2.9
25	22e	0.19	
	25	6.2	
	28	12.0	
	33a (= A)	5.5	25.0
	33b (= C)	10.0	>30.0
30	33c (= B)	8.6	20.0
	36a (= D)	4.7	
	36b	0.8	17.0
	39	2.5	
	43	20.0	

	47a		0.019	2.1
	47b		0.027	1.8
	54a	(= E)	0.15	2.7
	54b	(= M)	0.15	9.1
5	54c		1.2	>19.0
	54d		1.0	
	54e		3.5	
	54f		0.9	
	54g	(= G)	4.8	>20.0
10	54h		0.97	
	54i		0.054	2.4
	54j		0.28	
	54k		0.085	
	54l		0.215	7.0
15	63	(= Q)	0.85	4.1
	69a	(= R)	0.011	0.735
	69b	(= S)	0.050	0.745
	84a	(= V)	0.100	3.3
	84b	(= W)	0.019	0.50

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Example 5

Compounds of Example 4 were synthesized as follows:



3-Benzoylamino-4-oxo-4,6,7,8-tetrahydro-pyrrolo[1,2-a]pyrimidine-6-carboxylic acid methyl ester (3). A mixture of (4S)-2-amino-1-pyrroline-5-carboxylic acid ethyl ester hydrochloride (1, 0.44g, 2.38mmol; prepared in an analogous fashion as the methyl ester as described by Lee and Lown, J. Org. Chem., 52, 5717-21 (1987)); 4-ethoxymethylene-2-phenyl-2-oxazolin-5-one (2, 0.50g, 2.31mmol) and sodium methoxide (0.12g, 2.22mmol) in ethanol (10ml) was refluxed for 2h. The reaction was allowed to cool to room temperature and concentrated in vacuo. The residue was suspended in water and 1N sulfuric acid was added until pH 1 was reached. The aqueous mixture was extracted with dichloromethane, the organic layer was separated and concentrated in vacuo to yield 0.6g of a orange solid. Chromatography (flash, SiO<sub>2</sub>, 60% ethyl acetate/hexane increased to 100% ethyl acetate stepwise gradient, then 10% methanol/dichloromethane) to give 0.5g of an orange solid. A mixture of the orange solid and potassium cyanide (0.03g, 0.5mmol) in methanol (10ml) was refluxed overnight. The cooled reaction was concentrated in vacuo to give a yellow solid. Chromatography (flash, SiO<sub>2</sub>, 40% ethyl acetate/hexane to 100% ethyl acetate stepwise gradient) afforded 0.22g (31.6%) of the title compound: <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 2.25 (m, 1H), 2.65 (m, 1H), 3.15 (m, 2H), 3.75 (s, 3H), 5.15 (dd, 1H), 7.5 (t, 2H), 7.6 (t, 1H), 7.95 (d, 2H), 8.6 (s, 1H), 9.5 (s, 1H).

(3S)-[(3-benzoylamino-4-oxo-4,6,7,8-tetrahydro-pyrrolo[1,2-a]pyrimidine-6-carbonyl)-amino]-4-oxo-butanoic acid tert-butyl ester semicarbazone (5a and 5b). A mixture of 3-benzoylamino-4-oxo-4,6,7,8-tetrahydro-pyrrolo[1,2-a]pyrimidine-6-carboxylic acid ethyl ester (3, 0.22g 0.70mmol) and lithium hydroxide

5

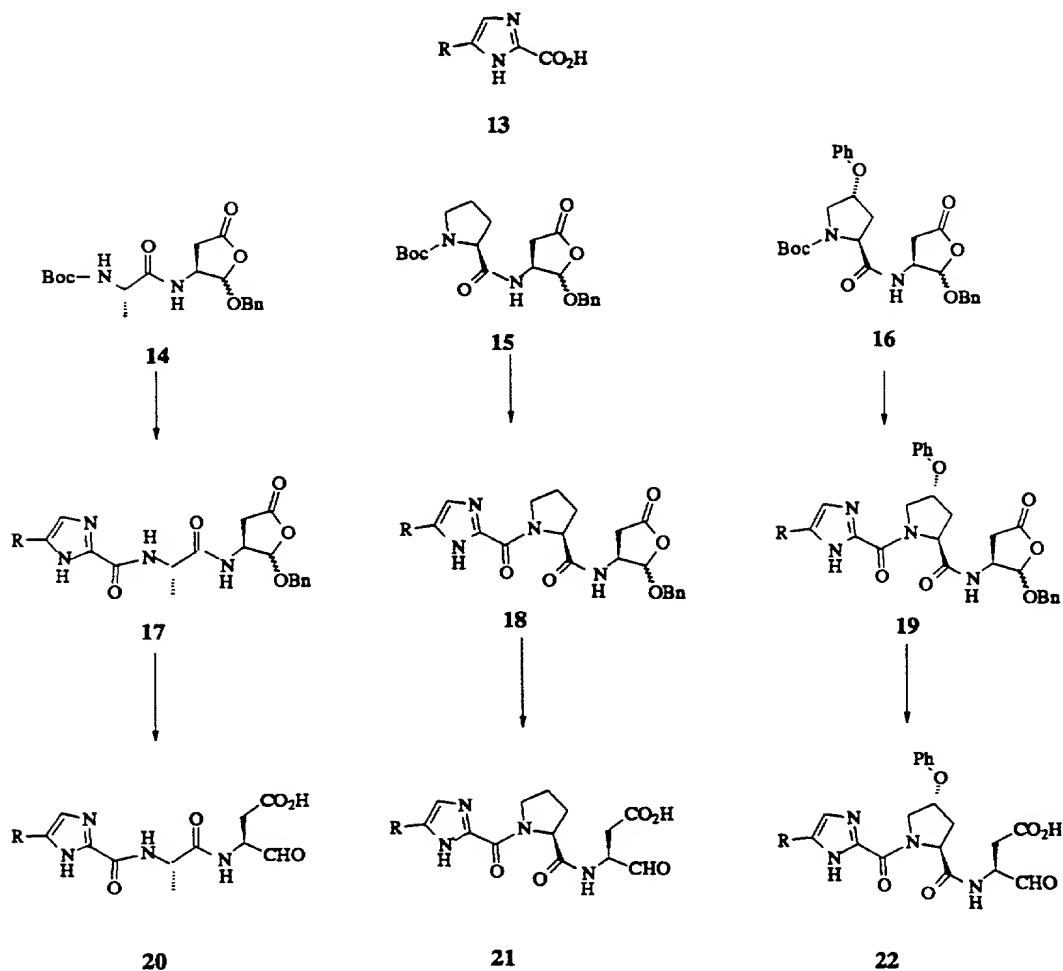
A 0°C mixture of (3S)-amino-4-oxo-butanoic acid tert-butyl ester semicarbazone (0.163g, 0.71mmol; Graybill et al., Int. J. Protein Res., 44, pp. 173-82 (1994)) and 3-benzoylamino-4-oxo-4,6,7,8-tetrahydropyrrolo[1,2-a]pyrimidine-6-carboxylic acid lithium salt (4) in dimethylformamide (5ml) and dichloromethane (5ml) was treated with hydroxybenzotriazole (0.104g, 0.77mmol) and 1-(3-dimethylaminopropyl)-3-ethyl carbodiimide hydrogen chloride (0.148g, 0.37mmol). The reaction was allowed to warm to room temperature and stirred 18hr. The reaction was poured onto water (50ml) and extracted with ethyl acetate (2 x 50mL). The combined organic layers were washed with aqueous 1M sodium hydrogen sulfate solution, dilute aqueous sodium hydrogen carbonate (50mL) and saturated aqueous sodium chloride. The organic layer was concentrated in vacuo to yield 0.43g of a yellow solid. Chromatography (flash, SiO<sub>2</sub>, ammonium hydroxide/methanol/dichloromethane (1:1:99 to 1:10:90 stepwise gradient)) gave 0.11g (30.9%) of the higher R<sub>f</sub> diastereomer (5a): <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 1.45 (s, 9H), 2.29-2.35 (m, 1H), 2.6-2.7 (m, 2H), 2.8 (dd, 1H), 3.1-3.15 (m, 1H), 3.2-3.3 (m, 1H), 4.9-4.95 (m, 1H), 5.2 (dd, 1H), 7.25 (d, 1H), 7.5-7.55 (m, 2H), 7.55-7.6 (m, 1H), 7.95 (d, 2H), 8.9 (s, 1H) and 0.11g (30.9%) of the lower R<sub>f</sub> diastereomer (5b): <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 1.45 (s, 9H), 2.3-2.4 (m, 1H), 2.6-2.7 (m, 1H), 2.7-2.8 (m, 2H), 3.1-3.15 (m, 1H), 3.2-3.3 (m, 1H), 4.85-4.95 (m, 1H), 5.15 (dd, 1H), 7.25



(d, 1H), 7.55 (t, 2H), 7.6 (t, 1H), 7.95 (d, 2H), 8.9 (s, 1H). Diastereomer 5a and diastereomer 5b were taken on separately.

(3S)-[(3-benzoylamino-4-oxo-4,6,7,8-tetrahydro-pyrrolo[1,2-a]pyrimidine-6-carbonyl)-amino]-4-oxo-butanoic acid (7a). A suspension of (3S)-[(3-benzoylamino-4-oxo-4,6,7,8-tetrahydro-pyrrolo[1,2-a]pyrimidine-6-carbonyl)-amino]-4-oxo-butanoic acid tert-butyl ester semicarbazone (5a, 0.11g, 0.22mmol) in dichloromethane (7.5ml) and trifluoroacetic acid (2.5ml) was stirred for 5h. The reaction was concentrated in vacuo, the residue was taken up in dichloromethane, concentrated in vacuo, suspended in toluene and concentrated in vacuo to give 0.07 g of (3S)-[(3-benzoylamino-4-oxo-4,6,7,8-tetrahydro-pyrrolo[1,2-a]pyrimidine-6-carbonyl)-amino]-4-oxo-butanoic acid semicarbazone (6a) as a white solid. The solid was suspended in a mixture of 37% aqueous formaldehyde/acetic acid/methanol (1:1:5) and stirred at room temperature for 18hr. The reaction was concentrated in vacuo, the residue was suspended in acetonitrile and concentrated in vacuo to give 0.1g of a white solid. Chromatography (HPLC, reverse phase C18, 1% to 75% acetonitrile/water (buffered with 0.1% trifluoroacetic acid) gradient elution) to give 0.05g (60%) of 7a as a white solid: RT = 7.9 min (HPLC, C18 reverse phase, 1 to 100% acetonitrile/water (0.1% trifluoroacetic acid buffer); 20 min gradient elution); <sup>1</sup>H NMR (CD<sub>3</sub>OD (existing as a 1:1 mixture of anomers of the hemi-acyloxy acetal form)) δ 2.25-2.4 (m, 1H), 2.45-2.8 (m, 4H), 3.05-3.15 (m, 1H), 4.25-4.35 (m, 1H), 4.55-4.6 (m, 1H), 5.1-5.2 (m, 1H), 7.45-7.65 (m, 3H), 7.9-8.0 (m, 2H), 8.9 (s, 1H).

10



- a**     **R = H**  
**b**     **R = PhCH<sub>2</sub>**  
**c**     **R = Ph(CH<sub>2</sub>)<sub>2</sub>**  
**d**     **R = Ph(CH<sub>2</sub>)<sub>3</sub>**  
**e**     **R = 4MeO-Ph(CH<sub>2</sub>)<sub>3</sub>**  
**f**     **R = 4HO-Ph(CH<sub>2</sub>)<sub>3</sub>**

Imidazole-2-carboxylic acids 13 were prepared using  
 modifications of described procedures (Yamanaka et al.,  
Chem. Pharm. Bull., 31, pp. 4549-53 (1983)); Suzuki et  
 al., J. Org. Chem., 38, pp. 3571-75 (1973)); and Oliver  
 et al. (J. Org. Chem., 38, pp. 1437-38 (1973)).

Imidazole-2-carboxylic acid (13a) was prepared according to Curtis and Brown, J. Org. Chem., 45, pp. 4038-40 (1980).

5 4-Benzylimidazole-2-carboxylic acid (13b), was isolated as an off-white solid: mp. 153-155°C; IR (KBr) 3026-2624, 1630, 1515, 1498, 1438, 1405; <sup>1</sup>H NMR(d<sub>6</sub>-DMSO) δ 7.31 (5H, m), 7.14 (1H, s), 3.95 (2H, s).

10 4-(2-Phenylethyl)imidazole-2-carboxylic acid (13c), was isolated as a pale yellow solid: mp. 151-153°C; IR (KBr) 3054-2617, 1637, 1497, 1376; <sup>1</sup>H NMR(d<sub>6</sub>-DMSO) δ 7.27 (5H, m), 7.11 (1H, s), 2.92 (4H, s).

15 4-(3-Phenylpropyl)imidazole-2-carboxylic acid (13d), was isolated as a pale yellow solid: mp. 148-150°C; IR (KBr) 3020-2615, 1636, 1509, 1498, 1383; <sup>1</sup>H NMR(d<sub>6</sub>-DMSO) δ 7.35-7.22 (5H, m), 7.01 (1H, s), 2.62 (4H, m), 1.94 (2H, m).

20 4-[3-(4-Methoxyphenyl)propyl]imidazole-2-carboxylic acid (13e), was isolated as a white crystalline solid: mp. 155-156°C (decomp.); IR (KBr) 3300-2300, 1633, 1513, 1376, 1244; <sup>1</sup>H NMR(d<sub>6</sub>-DMSO) δ 9.50-7.50 (2H, bs), 7.15 (1H, s), 7.11 (2H, d, J=8.5), 6.84 (2H, d, J=8.5), 3.71 (3H, s), 2.60-2.50 (4H, m), 1.86 (2H, m). Anal. Calcd for C<sub>14</sub>H<sub>16</sub>N<sub>2</sub>O<sub>3</sub>: C, 64.60; H, 6.20; N, 10.76. Found: C, 64.45; H, 6.21; N, 10.70.

25 4-[3-(4-Hydroxyphenyl)propyl]imidazole-2-carboxylic acid (13f). A solution of the ethyl ester of 13e (1.15g, 4.0mmol) in dry dichloromethane (50ml) was treated with boron tribromide (16ml, 1.0M solution in CH<sub>2</sub>Cl<sub>2</sub>, 16.0mmol) at 0°C. After 15min at 0°C, the

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mixture was warmed to 25°C and stirred for 16h. The reaction mixture was cooled in an ice bath and quenched with a dropwise addition of water (20ml). The resulting mixture was briefly stirred at 25°C then  
5 filtered. The filtrate was carefully neutralised by the addition of solid NaHCO<sub>3</sub> to afford **13f** (700mg, 71%) as a white solid: m.p. 186-187°C (decomp.) (recrystallised from MeOH); IR (KBr) 3500-2400, 2935, 1640, 1516, 1396, 1232; <sup>1</sup>H NMR(d<sub>6</sub>-DMSO) δ 9.83 (3H, bs),  
10 7.16 (1H, s), 6.98 (2H, d, J=8.2), 6.66 (2H, d, J=8.2), 2.60-2.40 (4H, m), 1.84 (2H, m). Anal. Calcd for C<sub>13</sub>H<sub>14</sub>N<sub>2</sub>O<sub>3</sub>: C, 63.40; H, 5.73; N, 11.38. Found: C, 62.96; H, 5.70; N, 11.27.

(2*R,S*, 3*S*) **N<sup>2</sup>-Tert-butoxycarbonyl-N-(tetrahydro-2-benzyloxy-5-oxo-3-furanyl)-L-alaninamide (14)**. Tri-*n*-butyl tin hydride (4.0ml, 14.9mmol) was added dropwise to a solution of (2*R,S*, 3*S*) 3-(*N*-allyloxycarbonyl) amino-2-benzyloxy-5-oxotetrahydrofuran (Chapman, Bioorg. Med. Chem. Lett., 2, pp. 613-18 (1992); (2.91g, 10mmol)), *N*-tert-butoxycarbonyl-L-alanine (2.08g, 11mmol) and bis(triphenylphosphine)palladium (II) chloride (150mg) in dichloromethane (75ml) until the colour of the solution turned dark orange. Hydroxybenzotriazole (2.70g, 20mmol) was added, and the  
20 mixture cooled to 0°C. 1-(3-dimethylamino-propyl)-3-ethylcarbodiimide hydrochloride (2.30g, 12mmol) was added then the mixture was allowed to warm slowly to room temperature during 4h. The mixture was diluted with ethyl acetate (250ml) and washed with 1*N*  
25 hydrochloric acid (3 x 150ml), saturated aqueous sodium bicarbonate (3 x 150ml) and brine (2 x 150ml), then dried (MgSO<sub>4</sub>), filtered and concentrated. The crude product was purified by column chromatography (50-70% ethyl acetate/hexane) to afford 3.17g (84%) of a  
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added to a solution of (2*R,S*, 3*S*) *N*<sup>2</sup>-tert-butoxycarbonyl-*N*-(tetrahydro-2-benzyloxy-5-oxo-3-furanyl)-*L*-alaninamide (**14**) (1.00g, 2.64mmol) in dichloromethane (7ml) at 0°C. The mixture was stirred at 0°C for 75 min. The mixture was concentrated, and the residue treated with diethyl ether then the ether was removed under vacuum. This procedure was repeated twice to yield a pale yellow glass. The solid was dissolved in DMF (20ml). Diisopropylethylamine (1.38ml, 7.92mmol) followed by 4-(3-phenylpropyl)imidazole-2-carboxylic acid (**13d**) (0.67g, 2.90mmol), 1-(3-dimethylaminopropyl)-3-ethyl carbodiimide hydrochloride (0.56g, 2.90mmol) and hydroxybenzotriazole (0.71g, 5.28mmol) were then added to this solution. The mixture was stirred at room temperature for 20h then poured into brine. The mixture was extracted with ethyl acetate (3 x 50ml). The combined organic extracts were washed with saturated aqueous sodium bicarbonate (2 x 100ml) then brine (2 x 100ml), dried (MgSO<sub>4</sub>), filtered and concentrated. The residue was purified by column chromatography (ethyl acetate) to afford 0.99g (76%) of **17d** as a mixture of diastereomers: IR (KBr) 3293, 3064, 2937, 1793, 1650, 1530, 1451, 1446, 1119; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.96 (brm), 7.62 (brd), 7.36-7.10 (10H, m), 6.88 (s), 6.86 (s), 5.53 (d, *J*=5.2), 5.48 (s), 4.87-4.52 (4H, m), 3.11-2.38 (2H, m), 2.65 (4H, m), 1.99 (2H, m), 1.47 (d, *J*=6.9), 1.46 (d, *J*=7.0).

The following compounds were prepared in a similar manner:

(2*R,S*, 3*S*) *N*<sup>2</sup>-(Imidazole-2-carbonyl)-*N*-(tetrahydro-2-benzyloxy-5-oxo-3-furanyl)-*L*-alaninamide (**17a**), was

isolated (74%) as a pale yellow solid: IR (KBr) 3289, 3056, 2937, 1793, 1664, 1642, 1528, 1453, 1440, 1124; <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 13.13 (1H, brs), 8.67 (d, J=7.0), 8.48 (d, J=7.8), 8.29 (d, J=6.8), 8.25 (d, J=7.6), 7.40-7.34 (6H, m), 7.11 (1H, s), 5.69 (d, J=5.0), 5.49 (d, J=0.8), 4.85-4.31 (4H, m), 3.19-2.42 (2H, m), 1.38 (d, J=7.4), 1.34 (d, J=7.4).

(2*R,S*, 3*S*) N<sup>2</sup>-(4-Benzylimidazole-2-carbonyl)-N-(tetrahydro-2-benzyloxy-5-oxo-3-furanyl)-L-alaninamide (17b), was isolated (75%) as a pale yellow glass: IR (KBr) 3294, 3031, 2937, 1792, 1650, 1530, 1453, 1444, 1119; <sup>1</sup>H NMR(CDCl<sub>3</sub>) δ 7.99 (brm), 7.75 (brd), 7.36-7.11 (10H, m), 6.81 (1H, s), 5.51, 5.45 (d, s, J=5.3), 4.85-4.47 (4H, m), 3.95 (2H, s), 3.04-2.72 (1H, m), 2.48-2.35 (1H, m), 1.44 (d, J=6.9), 1.43 (d, J=7.1).

(2*R,S*, 3*S*) N<sup>2</sup>-[4-(2-Phenylethyl)imidazole-2-carbonyl]-N-(tetrahydro-2-benzyloxy-5-oxo-3-furanyl)-L-alaninamide (17c), was isolated (79%) as a pale yellow glass: IR (KBr) 3292, 3029, 2936, 1793, 1650, 1530, 1453, 1444, 1119; <sup>1</sup>H NMR(CDCl<sub>3</sub>) δ 8.06 (brm), 7.70 (brs), 7.39-7.15 (10H, m), 6.82 (s), 6.81 (s), 5.53 (d, J=5.2), 5.48 (s), 4.87-4.53 (4H, m), 2.95 (4H, m), 3.11-2.37 (2H, m), 1.48 (d, J=5.6), 1.45 (d, J=6.7).

(2*R,S*, 3*S*) 1-[4-(2-Phenylethyl)imidazole-2-carbonyl]-N-(tetrahydro-2-benzyloxy-5-oxo-3-furanyl)-L-prolinamide (18c), was isolated (79%) as a pale yellow glass: IR (CH<sub>2</sub>Cl<sub>2</sub>) 3422, 2959, 1795, 1685, 1611, 1497, 1116; <sup>1</sup>H NMR(d<sub>6</sub>-DMSO) δ 12.78-12.59 (1H, m), 8.61-8.34 (1H, m), 7.39-7.22 (10H, m), 6.99-6.61 (1H, m), 5.71-5.26 (1H, m), 4.85-4.02 (4H, m), 3.63 (1H, m), 3.18-1.74 (11H, m).



(2*R,S*, 3*S*) 1-[4-(3-Phenylpropyl)imidazole-2-carbonyl]-  
N-(tetrahydro-2-benzyl-oxy-5-oxo-3-furanyl)-L-  
prolinamide (18d), was isolated (87%) as a colorless  
glass: IR (CH<sub>2</sub>Cl<sub>2</sub>) 3422, 3214, 2945, 1794, 1685, 1604,  
5 1496, 1117; <sup>1</sup>H NMR(d<sub>6</sub>-DMSO) δ 12.71 (1H, brm), 8.61-  
8.34 (1H, m), 7.45-7.18 (10H, m), 7.05-6.64 (1H, m),  
5.70-5.28 (1H, m), 4.85-4.02 (4H, m), 3.62 (1H, m)  
3.18-1.71 (13H, m).

(2*R,S*, 3*S*) 1-{4-[3-(4-Methoxyphenyl)propyl]imidazole-2-  
10 carbonyl}-N-(tetra-hydro-2-benzyloxy-5-oxo-3-furanyl)-  
L-prolinamide (18e), was isolated (72%) as a white  
glassy solid: mp. 62-65°C; IR (KBr) 3213, 2937, 1793,  
1680, 1606, 1606, 1512, 1245; <sup>1</sup>H NMR(d<sub>6</sub>-DMSO) δ 12.71,  
12.67, 12.58 (1H, 3 x bs), 8.60-8.30 (1H, m), 7.40-7.20  
15 (5H, m), 7.15-6.55 (5H, m), 5.66-5.20 (1H, m), 4.81-  
4.59 (2H, m), 4.55-4.05 (2H, m), 3.71 (3H, s), 3.65-  
3.45 (1H, m), 3.15-1.50 (13H, m). FABSMS m/e 547 (M<sup>+</sup>,  
100%), 439, 412, 340, 312, 243, 177, 154.

(2*R,S*, 3*S*) 1-{4-[3-(4-Hydroxyphenyl)propyl]imidazole-2-  
20 carbonyl}-N-(tetra-hydro-2-benzyloxy-5-oxo-3-furanyl)-  
L-prolinamide (18f), was isolated (70%) as a light  
yellow glassy solid: mp. 86-90°C; IR (KBr) 3298, 1790,  
1669, 1606, 1515, 1242; <sup>1</sup>H NMR(d<sub>6</sub>-DMSO) δ 12.66, 12.56  
(1H, 2 x bs), 9.14 (1H, s), 8.57-8.30 (1H, m), 7.36-  
25 7.30 (5H, m), 7.02-6.83 (3H, m), 6.70-6.57 (2H, m),  
5.65-5.28 (1H, m), 4.80-4.49 (2H, m), 4.50-4.05 (2H,  
m), 3.65-3.45 (1H, m), 3.15-1.55 (13H, m). FABMS m/e  
533 (M<sup>+</sup>, 100%), 425, 298, 229, 176, 154.

1-{5-[3-(4-Methoxyphenyl)propyl]-1H-imidazole-2-  
30 carbonyl}-4(R)-phenoxypyrrolidine-2(S)-carbonyl-  
(tetrahydro-2(R,S)-benzyloxy-5-oxofuran-3(S)-yl)amide  
(19e) was isolated (77%) as a clear colorless amorphous

solid. <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 9.95-9.75 (1H, m), 7.95 (1H, brs), 7.40-7.2 (7H, m), 7.2-6.78 (7H, m), 5.65-5.6 (1H, m), 5.55-5.45 (1H, m), 5.3-5.2 (1H, m), 5.15-5.0 (1H, m), 4.95-4.75 (1H, m), 4.7-4.6 (1H, m), 4.5-4.4 (1H, m), 4.35-4.4.25 (1H, m), 3.8 (3H, s), 3.05-1.75 (10H, m).

(3S) 3-{N-[4-(3-Phenylpropyl)imidazole-2-carbonyl]-L-alaninyl}amino-4-oxo-butanoic acid (20d). A mixture of (2R,S, 3S) N<sup>2</sup>-[4-(3-Phenylpropyl)imidazole-2-carbonyl]-N-(tetrahydro-2-benzyloxy-5-oxo-3-furanyl)-L-alaninamide (0.93g, 1.90mmol) and 10% palladium on activated carbon (0.93g) in methanol (100ml) was stirred under a hydrogen atmosphere for 5h. The resulting mixture was filtered and concentrated to yield a colorless glass. Recrystallization from methanol-diethyl ether afforded 401mg (53%) of 20d as a colorless solid: mp. 94-96°C; [α]<sub>D</sub><sup>27</sup> +16.4° (c 0.5, MeOH); IR (KBr) 3300, 3287, 1786, 1732, 1659, 1651, 1532, 1451; <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 7.19 (5H, m), 6.91 (1H, s), 4.60-4.46 (2H, m), 4.27 (1H, m), 2.63 (4H, m), 2.75-2.40 (2H, m), 1.96 (2H, m), 1.44 (3H, d, J=7.0).

The following compounds were prepared in a similar manner:

(3S) 3-[N-(Imidazole-2-carbonyl)-L-alaninyl]amino-4-oxobutanoic acid (20a; E), was isolated (83%) as a colorless solid: mp. 115°C; [α]<sub>D</sub><sup>25</sup> +4.4° (c 0.5, MeOH); IR (KBr) 3303, 1782, 1658, 1650, 1563, 1521, 1454; <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 7.18 (2H, s), 4.55 (2H, m), 4.27 (1H, m), 2.56 (2H, m), 1.45 (d, J=7.1), 1.44 (d, J=7.0).

(3S) 3-[N-(4-Benzylimidazole-2-carbonyl)-L-alaninyl]amino-4-oxobutanoic acid (20b), was isolated (56%) as a colorless solid: mp. 113-115°C; [α]<sub>D</sub><sup>29</sup> +18.2°

(c 0.5 MeOH). IR (KBr) 3301, 3288, 1783, 1727, 1650, 1531, 1452;  $^1\text{H}$  NMR( $\text{CD}_3\text{OD}$ )  $\delta$  7.25 (5H, m), 6.90 (1H, s), 4.59-4.45 (2H, m), 4.26 (1H, m), 3.95 (2H, s), 2.74-2.39 (2H, m), 1.42 (3H, d,  $J=7.0$ ). Anal. Calcd for  $\text{C}_{18}\text{H}_{20}\text{O}_4\text{O}_5$ : C, 56.69; H, 5.55; N, 14.69. Found: C, 57.06; H, 5.54; N, 14.41.

(3S) 3-{N-[4-(2-Phenylethyl)imidazole-2-carbonyl]-L-alaninyl}amino-4-oxobutanoic acid (20c; N), was isolated (53%) as a colorless solid: mp. 102-104°C;  $[\alpha]_D^{27} +13.7^\circ$  (c 0.5, MeOH); IR (KBr) 3299, 3289, 1785, 1732, 1650, 1531, 1452;  $^1\text{H}$  NMR( $\text{CD}_3\text{OD}$ )  $\delta$  7.20 (5H, m), 6.82 (1H, s), 4.60-4.46 (2H, m), 4.29 (1H, m), 2.92 (4H, s), 2.76-2.41 (2H, m), 1.44 (3H, 2 x d,  $J=7.1$ ). Anal. Calcd for  $\text{C}_{19}\text{H}_{22}\text{N}_4\text{O}_5 \cdot \text{H}_2\text{O}$ : C, 56.43; H, 5.98; N, 13.85. Found: C, 56.65; H, 5.84; N, 13.91.

(3S) 3{N-[4-(2-Phenylethyl)imidazole-2-carbonyl]-L-prolinyl}amino-4-oxobutanoic acid (21c), was isolated (85%) as a colorless glass: mp. 101-103°C (methanol-diethyl ether);  $[\alpha]_D^{27} -63.8^\circ$  (c 0.25, MeOH); IR (KBr) 3275, 1784, 1728, 1664, 1606, 1498, 1429;  $^1\text{H}$  NMR( $\text{CD}_3\text{OD}$ )  $\delta$  7.24 (5H, m), 6.83 (s), 6.79 (s), 4.58-4.14 (3H, m), 3.69 (1H, m), 2.93 (4H, brs), 2.75-1.99 (6H, m). Anal. Calcd for  $\text{C}_{21}\text{H}_{24}\text{N}_4\text{O}_5 \cdot \text{H}_2\text{O}$ : C, 58.60; H, 6.09; N, 13.02. Found: C, 58.34; H, 5.96; N, 12.67.

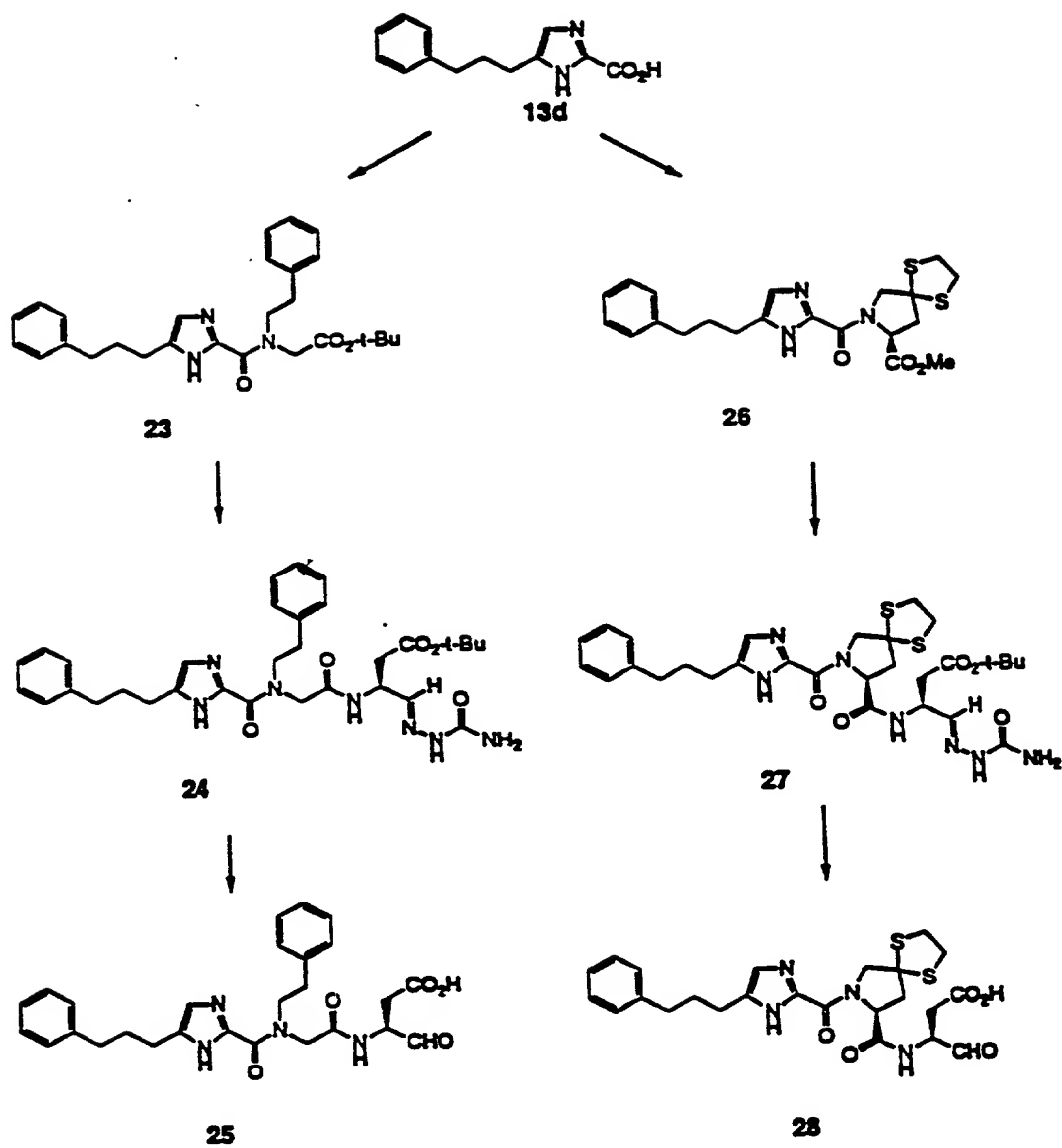
(3S) 3-{N-[4-(3-Phenylpropyl)imidazole-2-carbonyl]-L-prolinyl}amino-4-oxo-butanoic acid (21d), was isolated (81%) as a colorless glass: mp. 91-94°C; (methanol-diethyl ether);  $[\alpha]_D^{25} -68^\circ$  (c 0.25, MeOH); IR (KBr) 3277, 2939, 1784, 1727, 1662, 1606, 1498, 1429;  $^1\text{H}$  NMR( $\text{CD}_3\text{OD}$ )  $\delta$  7.29-7.16 (5H, m), 6.92 (s), 6.86 (s), 4.58-4.16 (3H, m), 3.71 (1H, m), 2.75-1.92 (13H, m). Anal. Calcd for  $\text{C}_{22}\text{H}_{26}\text{N}_4\text{O}_5 \cdot \text{H}_2\text{O}$ : C, 59.45; H, 6.35; N,

12.60. Found: C, 59.75; H, 6.21; N, 12.41.

(3S) 3-{N-[4-[3-(4-Methoxyphenyl)propyl]imidazole-2-carbonyl]-L-prolinyl}amino-4-oxobutanoic acid (21e),  
was isolated (65%) as a white glassy solid: mp. 101-  
105°C;  $[\alpha]_D^{23}$  -60.6 (c 0.05, MeOH); IR (KBr) 3231, 1784,  
1726, 1611, 1512, 1245;  $^1\text{H}$  NMR( $\text{CD}_3\text{OD}$ )  $\delta$  7.09 (2H, d,  $J=8.6$ ), 6.92, 6.85 (1H, 2 x s), 6.81 (2H, d,  $J=8.6$ ),  
5.45-5.30 (1H, m), 4.64-4.46 (1H, m), 4.28-4.10 (2H, m), 3.75 (3H, s), 3.74-3.66 (1H, m), 2.67-1.84 (13H, m). Anal. Calcd for  $\text{C}_{23}\text{H}_{28}\text{N}_4\text{O}_6 \cdot \text{H}_2\text{O}$ : C, 58.22; H, 6.37; N, 11.81. Found: C, 58.39; H, 6.34; N, 11.45; FABMS m/e 457 ( $\text{M}^+$ ), 405, 312, 243, 215, 176, 154 (100%).

(3S) 3-{N-[4-[3-(4-Hydroxyphenyl)propyl]imidazole-2-carbonyl]-L-prolinyl}amino-4-oxobutanoic acid (21f),  
was isolated (43%) as a white glassy solid: mp. 114-118°C;  $[\alpha]_D^{25}$  -55.7° (c 0.05, MeOH); IR (KBr) 3288, 2935, 1780, 1715, 1662, 1610, 1515, 1441;  $^1\text{H}$  NMR( $\text{CD}_3\text{OD}$ )  $\delta$  6.99 (2H, d,  $J=8.5$ ), 6.91, 6.85 (1H, 2 x s), 6.68 (2H, d,  $J=8.5$ ), 5.45-5.30 (1H, m), 4.60-4.47 (1H, m), 4.30-4.10 (2H, m), 3.80-3.55 (1H, m), 2.70-1.80 (13H, m). Anal. Calcd for  $\text{C}_{22}\text{H}_{26}\text{N}_4\text{O}_6 \cdot \text{H}_2\text{O}$ : C, 57.38; H, 6.13; N, 12.17. Found: C, 57.68; H, 6.25; N, 11.66. FABMS m/e 443 ( $\text{M}^+$ ), 298, 229, 154 (100%).

3(S)-[(1-{5-[3-(4-Methoxyphenyl)propyl]-1H-imidazole-2-carbonyl}-4(R)-phenoxy pyrrolidine-2(S)-carbonyl)amino]-4-oxobutanoic acid (22e) was isolated (43%) as a beige solid:  $^1\text{H}$  NMR ( $\text{CD}_3\text{OD}$ )  $\delta$  7.35-7.2 (3H,m), 7.15-7.0 (2H,m), 6.98-6.85 (3H, m), 6.83-6.77 (2H,d), 5.4-5.1 (1H,m), 4.65-4.5 (1H,m), 4.35-4.2 (2H,m), 4.15-3.90 (1H,m), 3.78 (3H, s), 3.62-3.48 (1H, m), 2.78-2.25 (8H, m), 2.02-1.9 (2H,m).



**{Phenethyl-[5-(3-propyl)-1H-imidazole-2-carbonyl]amino}acetic acid tert-butyl ester (23).**

A 0°C solution of 4-(3-phenylpropyl)-imidazole-2-carboxylic (13d) (150mg, 0.65mmol) and N-(2-phenethyl)glycine tert-butyl ester (140 mg, 0.59 mmol) in 5 ml of anhydrous dimethylformamide was treated with diisopropylethylamine (154µl, 0.89mmol), hydroxybenzotriazole (160 mg, 1.18 mmol), and 1-(3-dimethylaminopropyl)-3-ethyl carbodiimide hydrochloride (136 mg, 0.71 mmol). After stirring for 36 h, the reaction was poured onto saturated aqueous sodium chloride and extracted with ethyl acetate (3 x 50ml). The combined organic extracts were washed twice with saturated aqueous sodium bicarbonate (2x) and saturated aqueous sodium chloride (1x), dried (Na<sub>2</sub>SO<sub>4</sub>), filtered, and concentrated in vacuo to give a brown oil. Chromatography (flash, SiO<sub>2</sub>, 30% ethyl acetate/hexane) to give 160mg (61%) of **23** as a white solid: <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.38-7.14 (10H, m), 6.85-6.8 (1H, m), 4.84-4.76 (1H, d), 4.5-4.42 (1H, m), 4.07-4.0 (1H, d), 3.78-3.72 (1H, m), 3.12-2.94 (2H, 2 x m), 2.75-2.55 (4H, m), 2.1-1.95 (2H, m), 1.5-1.45 (9H, 3 x s).

**(3S)-(2-Phenethyl-[5-(3-phenylpropyl)-1H-imidazole-2-carbonyl]amino}acetyl amino) 4-oxobutanoic acid tert-butyl ester semicarbazone (24).** The ester **23** (160mg, 0.357mmol) was treated with 25% trifluoroacetic acid/dichloromethane (7ml) for 4 h. The reaction was concentrated in vacuo to afford 180mg of the acid. The acid (180 mg, 0.357mmol) was coupled to (3S)-3-amino-4-oxobutanoic acid tert-butyl ester semicarbazone (161mg, 0.357mmol) as describe for the preparation of **5a** and **5b** to give 86 mg (33%) of **24** (one diastereomer) as a white solid : <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 10.9-10.3 (1H, 2 d), 10.08-9.78 (1H, 2 d), 9.25-9.15 (1H, m), 8.35-8.10 (1H, 2 m),

7.9-7.85 (1H, 2 s), 7.40-7.05 (10H, m), 6.9-6.75 (1H,m), 6.3-5.8 (1H, br s), 5.2-4.65 (2H,m), 4.35-3.5 (3H,m), 3.25-3.0 (2H, m), 2.9-2.45 (6H,m), 2.05-1.8 (2H,m), 1.4 (9H,s).

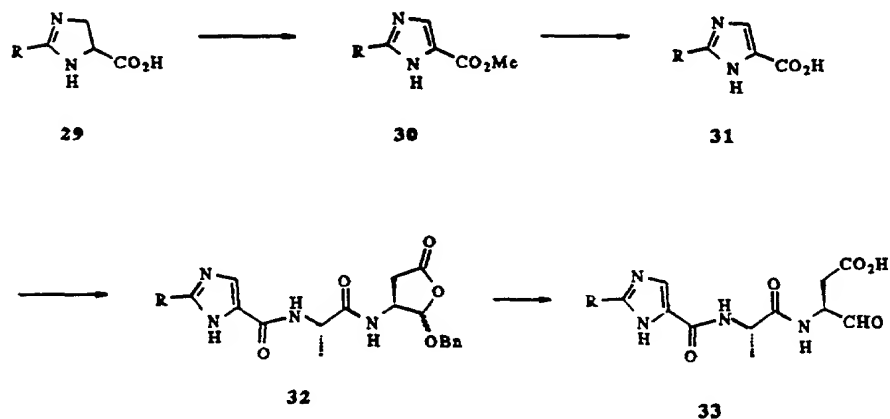
5      **(3S) - (2-{Phenethyl-[5-(3-phenylpropyl)-1H-imidazole-2-carbonyl]amino}acetyl-amino)-4-oxobutanoic acid trifluoroacetic acid salt (25)** was prepared by the method described for **7a** to afford 32 mg (82%) as a white solid: <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 7.05-7.35 (m, 11H), 4.65  
10      (m, 1H), 4.4 (m, 1H), 4.3 (s, 2H), 3.6-4.0 (m, 2H), 2.5-2.95 (m, 8H), 2.05 (m, 2H).

**7-[5-(3-Phenylpropyl)-1H-imidazole-2-carbonyl]-1,4-dithia-7-azaspiro[4.4]nonane-8(S)-carboxylic acid methyl ester (26).** 4-(3-Phenylpropyl)imidazole-2-  
15      carboxylic acid (**13d**) was coupled to 1,4-dithia-7-azaspiro[4.4]nonane-8(S)-carboxylic acid methyl ester hydrobromide (Smith et. al., J. Med. Chem., 31, pp. 875-85 (1988)) by the method described for **23** to afford 140 mg (65%) as a yellow gum: <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.34-  
20      7.15 (5H, m), 6.98-6.8 (1H, 3 s), 5.7-5.65 (0.5 H, m), 5.2-5.1 (1H,m), 4.82-4.75 (0.5H, m), 4.4-4.35 (1H, m), 4.05 (1H,d), 3.75-3.7 (3H, 2 s), 3.4-3.3 (4H,m), 2.95-2.45 (8H, m), 2.05-1.95 (2H,m).

**(3S) - ({7-[5-(3-Phenylpropyl)-1H-imidazole-2-carbonyl]-1,4-dithia-7-azaspiro[4.4]nonane-8(S)-carbonyl}-amino)-4-oxobutanoic acid tert-butyl ester semicarbazone (27).**  
25      Following the procedure described for **4**, the ester **26** was converted to its acid which was subsequently coupled to (3S)-3-amino-4-oxobutanoic acid tert-butyl  
30      ester semicarbazone as described for **24** to give 70 mg (33%) as a brown solid : <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 7.28-7.10 (5H,m), 6.90 (1H, br s), 4.94 (1H, m), 3.96-3.86

(2H,q), 3.35-3.25 (4H,d), 3.0 (2H, s), 2.73-2.59 (6H, m), 2.0-1.92 (2H, m), 1.44 (9H,s).

(3S)-({7-[5-(3-Phenylpropyl)-1H-imidazole-2-carbonyl]-1,4-dithia-7-azaspiro[4.4]nonane-8(S)-carbonyl}-amino)-4-oxobutanoic acid (28) was prepared by the method described for 7a to afford 17 mg (26%) as a light brown solid:  $^1\text{H}$  NMR ( $\text{CD}_3\text{OD}$ )  $\delta$  7.4 (s, 1H), 7.1-7.25 (m, 5H), 4.9 (m, 1H), 4.6 (m, 1H), 4.3 (m, 1H), 3.95 (s, 2H), 3.25-3.4 (m, 4H), 3.0 (d, 2H), 2.6-2.8 (m, 5H), 2.45 (m, 1H), 2.05 (m, 2H).



- a     R =  $\text{Ph}(\text{CH}_2)_2$
- b     R =  $4\text{CF}_3\text{-Ph}(\text{CH}_2)_2$
- c     R =  $\text{PhCH}_2$

4,5-Dihydroimidazole-4-carboxylic esters (29) were prepared by a modification of the procedure described by Jones et al., Tetrahedron Lett., 29, pp. 3853-56 (1988).

(4R,S) Methyl 2-(2-phenylethyl)-4,5-dihydroimidazole-4-carboxylate (29a). Dry hydrogen chloride was bubbled



into a solution of hydrocinnamitrile (3.28ml, 25mmol) in methanol (125ml) at 0°C for 45 mins. The solvents were removed to give the imidate salt which was dissolved in methanol (125ml) along with methyl 2,3-diaminopropionate (25mmol) (Jones et al., supra). The mixture was kept at room temperature for 2.5h, then concentrated to a yellow oil. The crude product was purified by column chromatography (10-20% methanol/dichloromethane) to afford 3.52g (61%) of a colorless glass: <sup>1</sup>H NMR(CDCl<sub>3</sub>) δ 7.30-7.15 (5H, m), 4.63 (1H, t, J=9.7), 3.96 (2H, d, J=9.7), 3.72 (3H, s), 3.10 (4H, m), <sup>13</sup>C NMR(CDCl<sub>3</sub>) δ 171.3, 168.8, 138.3, 128.4, 128.2, 126.6, 57.3, 53.0, 47.7, 31.7, 27.9.

(4*R,S*) Methyl 2-[2-(4-trifluoromethylphenyl)ethyl]-4,5-dihydroimidazole-4-carboxylate (29b), was prepared by the method described for 29a to yield 6.80g (78%) of a colorless solid: mp. 136-141°C; <sup>1</sup>H NMR(CDCl<sub>3</sub>) δ 7.45 (4H, s), 4.71 (1H, dd, J=8.6,10.8), 4.02 (2H, m), 3.73 (3H, s), 3.19 (4H, m).

Imidazole-4-carboxylic esters 30 were prepared by a modification of the procedure described by Martin et al., J. Org. Chem., 33, pp. 3758-61 (1968).

**Methyl 2-(2-phenylethyl)imidazole-4-carboxylate (30a).**  
A mixture of (4*R,S*) methyl 2-(2-phenylethyl)-4,5-dihydroimidazole-4-carboxylate (29a) (3.40g, 14.64mmol), chloroform (75ml) and manganese (IV) oxide (13.0g, 150mmol) was heated under reflux for 21h then filtered hot. The solids were washed with chloroform and methanol. The combined filtrates were concentrated to leave a yellow-brown solid, which was purified by column chromatography (2-5% methanol/dichloromethane) to afford 1.46g (43%) of a pale yellow solid: mp. 151-

155°C; IR (KBr) 3028, 2946, 1720, 1533, 1433, 1348, 1195, 1166;  $^1\text{H}$  NMR( $\text{CDCl}_3$ )  $\delta$  7.62 (1H, s), 7.26-7.02 (5H, m), 3.82 (3H, s), 3.03 (4H, brs),  $^{13}\text{C}$  NMR( $\text{CDCl}_3$ )  $\delta$  162.9, 150.2, 140.3, 128.5, 128.2, 126.3, 51.5, 34.5, 30.4. Anal. Calcd for  $\text{C}_{13}\text{H}_{14}\text{N}_2\text{O}_2$  : C, 67.81; H, 6.13; N, 12.16. Found: C, 67.70; H, 6.15; N, 12.16.

Methyl 2-[2-(4-trifluoromethylphenyl)ethyl]imidazole-4-carboxylate (30b), was prepared by the method described for 30a. It was recrystallised from ethyl acetate to afford 1.88g (33%) of cream crystals: mp. 225-26°C; IR (KBr) 3239, 2951, 1715, 1532, 1331, 1158, 1105, 1068;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  7.61 (1H, s), 7.54 (2H, d,  $J = 8.1$ ), 7.26 (2H, d,  $J = 8.1$ ), 3.89 (3H, s), 3.10 (4H, m). Anal. Calcd for  $\text{C}_{14}\text{H}_{13}\text{F}_3\text{N}_2\text{O}_2$ : C, 56.38; H, 4.39; N, 9.39; F, 19.11. Found: C, 56.23; H, 4.44; N, 9.33; F, 19.08.

2-(2-Phenylethyl)imidazole-4-carboxylic acid (31a). A mixture of methyl 2-(2-phenylethyl)imidazole-4-carboxylate (31a) (1.38g, 6mmol), methanol (30ml) and 1M aqueous sodium hydroxide (30ml) was heated under reflux for 16h. The methanol was removed under reduced pressure, and the resulting aqueous solution was neutralized with 4M hydrochloric acid, whereupon a pale yellow solid precipitated. The precipitate was collected, washed with water, and dried to afford 1.18g (91%) of a pale yellow solid: mp. 117-120°C; IR (KBr) 3375, 3131, 2616, 2472, 1638, 1592, 1551, 1421, 1388, 1360;  $^1\text{H}$  NMR( $d_6$ -DMSO)  $\delta$  7.59 (1H, s), 7.26 (5H, m), 2.99 (4H, m). Anal. Calcd for  $\text{C}_{12}\text{H}_{12}\text{N}_2\text{O}_2 \cdot 0.25\text{H}_2\text{O}$ : C, 65.29; H, 5.71; N, 12.69. Found: C, 65.00; H, 5.64; N, 12.58.

2-[2-(4-Trifluoromethylphenyl)ethyl]imidazole-4-carboxylic acid (31b), was prepared by the method described for 31a to afford 1.09g (76%) of a pale

yellow solid: mp. 126-130°C; IR (KBr) 3339, 2640-2467, 1638, 1589, 1545, 1383, 1323; <sup>1</sup>H NMR(d<sub>6</sub>-DMSO) δ 7.69 (2H, d, J=8.0), 7.59 (1H, s), 7.47 (2H, d, J=8.0), 3.06 (4H, m).

- 5 (2*R,S*, 3*S*) N<sup>2</sup>-[2-(2-Phenylethyl)imidazole-4-carbonyl]-N-(tetrahydro-2-benzyl-oxy-5-oxo-3-furanyl)-L-alaninamide (32a). To a solution of (2*R,S*, 3*S*) N<sup>2</sup>-tert-butoxycarbonyl-N-(tetrahydro-2-benzyloxy-5-oxo-3-furanyl)-L-alaninamide (14) (1.59g, 4.20mmol; Chapman, *Biorg. Med. Chem. Lett.*, 2, pp. 613-18 (1992)) in 10 dichloromethane (15ml), cooled to 0°C, was added trifluoroacetic acid (15ml). The mixture was stirred at 0°C for 1h and then concentrated. The residue was treated with ether and then the ether was removed under 15 vacuum. This procedure was repeated twice to yield a pale yellow glass. The solid was dissolved in DMF (20ml), then diisopropylethylamine (2.19ml, 12.6mmol), 2-(2-phenylethyl)imidazole-4-carboxylic acid (31a) (1.0g, 4.62mmol), 1-(3-dimethylaminopropyl)-3-ethyl 20 carbodiimide hydrochloride (0.89g, 4.62mmol) and hydroxybenzotriazole (1.14g, 8.40mmol) were added to the solution. The reaction mixture was stirred at room temperature for 20h then poured into brine. The mixture was extracted with ethyl acetate (3 x 50ml). 25 The combined organic extracts were washed with saturated aqueous sodium bicarbonate (3 x 100ml) then brine (3 x 100ml), dried (MgSO<sub>4</sub>) and concentrated. The residue was purified by column chromatography (2-10% isopropanol in dichloromethane then 0-6% isopropanol in 30 ethyl acetate) to yield 1.10g (55%) of 32a as a mixture of diastereomers: IR (KBr) 3278, 3065, 1790, 1641, 1577, 1545, 1499, 1454, 1120; <sup>1</sup>H NMR(CDCl<sub>3</sub>) δ 10.26 (1H, s), 8.14 (1H, s), 7.66 (d, J=7.0), 7.56 (d, J=7.0), 7.43 (1H, s), 7.31-7.11 (10H, m), 5.49 (d, J=5.6), 5.48

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(s), 4.83-4.41 (4H, m), 3.04-2.41 (2H, m), 2.99 (4H, s), 1.45 (d,  $J=7.0$ ), 1.44 (d,  $J=7.0$ ).

(2*R,S*, 3*S*)  $N^2$ -{2-[2-(4-Trifluoromethylphenyl)ethyl]imidazole-4-carbonyl}-*N*-(tetrahydro-2-benzyloxy-5-oxo-3-furanyl)-*L*-alaninamide (32b), was prepared by the method described for 32a to afford 1.08g (62%) of a pale yellow glass: IR (KBr) 3376, 3284, 3070, 2938, 1791, 1642, 1578, 1546, 1327, 1165, 1122, 1068;  $^1\text{H}$  NMR(CDCl<sub>3</sub>)  $\delta$  7.95 (0.5H, m), 7.55-7.25 (11.5H, m), 5.53 (s), 5.49 (d,  $J=5.3$ ), 4.88-4.48 (4H, m), 3.11-2.96 (4H, m), 2.91 (1H, m), 2.51 (1H, m), 1.47 (3H, d,  $J=7.1$ ).

(2*R,S*, 3*S*)  $N^2$ -(2-Benzylimidazole-4-carbonyl)-*N*-(tetrahydro-2-benzyloxy-5-oxo-3-furanyl)-*L*-alaninamide (32c), was prepared by the method described for 32a from 2-benzylimidazole-4-carboxylic acid (Ger. Offen. DE 3427136) to afford 1.13g (83%) of a yellow glass: IR (CH<sub>2</sub>Cl<sub>2</sub>) 3433, 3062, 2990, 1803, 1693, 1584, 1504, 1429, 1285, 1258;  $^1\text{H}$  NMR(CDCl<sub>3</sub>)  $\delta$  9.50 (s), 9.37 (s), 7.86 (0.5H, d,  $J=6.1$ ), 7.56-7.21 (10.5H, m), 7.48 (1H, s), 5.51 (d,  $J=5.2$ ), 5.48 (s), 4.87-4.41 (4H, m), 4.08 (s), 4.07 (s), 3.03-2.39 (2H, m), 1.46 (3H, d,  $J=7.0$ ).

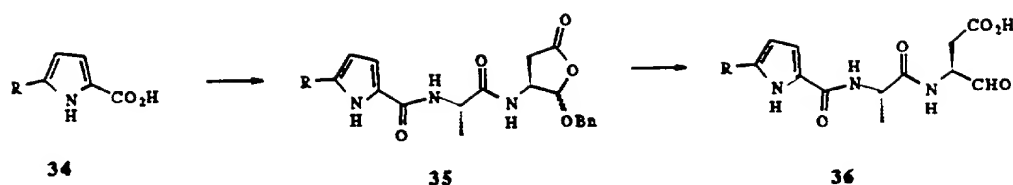
(3*S*) 3-{*N*-[2-(2-Phenylethyl)imidazole-4-carbonyl]-*L*-alaninyl}amino-4-oxobutanoic acid (33a; A). A mixture of (2*R,S*, 3*S*)  $N^2$ -[2-(2-phenylethyl)imidazole-4-carbonyl]-*N*-(tetrahydro-2-benzyloxy-5-oxo-3-furanyl)-*L*-alaninamide (32a) (1.0g, 2.10mmol) and 10% palladium on activated carbon (1.0g) in methanol (50ml) was stirred under a hydrogen atmosphere for 4.5h. The resulting mixture was filtered and concentrated to yield a colorless glass. Recrystallization from methanol-diethyl ether afforded 510mg (63%) of a colorless

solid: mp. 127°C; IR (KBr) 3360, 3279, 2981, 1781, 1732, 1646, 1577, 1547; <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 7.54 (1H, s), 7.29-7.12 (5H, m), 4.60-4.47 (2H, m), 4.28 (1H, m), 3.01 (4H, s), 2.76-2.39 (2H, m), 1.43 (3H, 2 x d, J=7.0, J=7.0), <sup>13</sup>C NMR (CD<sub>3</sub>OD) δ 176.2, 176.0, 174.7, 174.6, 164.4, 164.3, 150.5, 141.9, 134.8, 129.5, 129.3, 127.3, 122.3, 98.8, 98.4, 52.3, 52.0, 50.3, 35.6, 31.2, 18.8, 18.7. Anal. Calcd for C<sub>19</sub>H<sub>22</sub>N<sub>4</sub>O<sub>5</sub> · H<sub>2</sub>O: C, 56.43; H, 5.98; N, 13.85. Found: C, 56.78; H, 5.70; N, 13.77.

10 (3S) 3-{N-[2-(2-[4-Trifluoromethylphenyl]ethyl)imidazole-4-carbonyl]-L-alaninyl}-amino-4-oxobutanoic acid (33b; C), was prepared by the method described for 33a to afford 612mg (73%) of a colorless solid: mp. 120-124°C; [α]<sub>D</sub><sup>23</sup> +14.3° (c 0.5, MeOH); IR (KBr) 3287, 2985, 2937, 1782, 1732, 1646, 1579, 1547, 1327; <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 7.56 (2H, d, J=8.0), 7.54 (1H, s), 7.36 (2H, d, J=8.0), 4.60-4.48 (2H, m), 4.28 (1H, m), 3.08 (4H, m), 2.75-2.41 (2H, m), 1.43 (3H, d, J=7.0). Anal. Calcd for C<sub>20</sub>H<sub>21</sub>F<sub>3</sub>N<sub>4</sub>O<sub>5</sub> · 0.5H<sub>2</sub>O : C, 51.84; H, 4.78; N, 12.09; F, 12.30. Found: C, 51.83; H, 4.72; N, 12.14; F, 12.36.

25 (3S) 3-[N-(2-Benzylimidazole-4-carbonyl)-L-alaninyl]amino-4-oxobutanoic acid (33c; B), was prepared by the method described for 33a to afford 426mg (64%) of a colorless solid: [α]<sub>D</sub><sup>23</sup> +13.4° (c 0.407, MeOH). IR (KBr) 3260, 3150, 2980, 1779, 1727, 1649, 1573, 1547; <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 7.58 (1H, s), 7.34-7.22 (5H, m), 4.59-4.47 (2H, m), 4.28 (1H, m), 4.07 (2H, s), 2.74-2.41 (2H, m), 1.42 (3H, d, J=6.7); <sup>13</sup>C NMR (CD<sub>3</sub>OD) δ 175.6, 175.5, 175.0, 164.6, 164.5, 150.1, 138.7, 135.3, 130.0, 129.9, 128.2, 122.9, 98.9, 98.5, 52.5, 52.2, 35.5, 35.1, 35.0, 19.0, 18.9. Anal. Calcd for C<sub>18</sub>H<sub>20</sub>N<sub>4</sub>O<sub>5</sub> · H<sub>2</sub>O: C, 55.37; H, 5.68; N, 14.35. Found C,

55.83; H, 5.75; N, 13.96. MS(FAB, m/z) : 373 ( $M^+$ ), 228, 185, 91.



- (a) R = H  
(b) R = CH<sub>2</sub>Ph

5 **5-Benzylpyrrole-2-carboxylic acid (34b).** A mixture of  
Ethyl 5-benzylpyrrole-2-carboxylate (0.7g, 3.05mmol;  
Elder et al., Synthetic Communications, 19, 763-767  
(1989)), ethanol (20ml) and 1M sodium hydroxide (9.2ml,  
9.2mmol) was stirred and heated under reflux for 3h.  
10 The major part of the ethanol was removed and the  
remaining liquid was diluted with water, washed with  
ether, cooled in ice and acidified with concentrated  
hydrochloric acid. The mixture was extracted with  
ether. The combined extracts were washed with brine,  
15 dried (Na<sub>2</sub>SO<sub>4</sub>) and concentrated to afford 0.567g (92%)  
of an off white solid: mp. 130-134°C; <sup>1</sup>H NMR(CDCl<sub>3</sub>) δ  
8.87 (1H, brs), 7.37-6.95 (5H, m), 6.97 (1H, m), 6.07  
(1H, m), 4.00 (2H, s).

20 **(2R,S, 3S) N<sup>2</sup>-(Pyrrole-2-carbonyl)-N-(tetrahydro-2-  
benzyloxy-5-oxo-3-furanyl)-L-alaninamide (35a).** A  
solution of (2R,S, 3S) N<sup>2</sup>-tert-butoxycarbonyl-N-  
(tetrahydro-2-benzyloxy-5-oxo-3-furanyl)-L-alaninamide  
(14) (756mg, 2.0mmol) in dry dichloromethane (8ml) at  
0°C was treated with trifluoroacetic acid (8ml) for 1h  
25 and then evaporated to dryness. Dry ether was added to  
the residue and the mixture concentrated to give a  
viscous oil. The oil was dissolved in dry DMF (10ml).

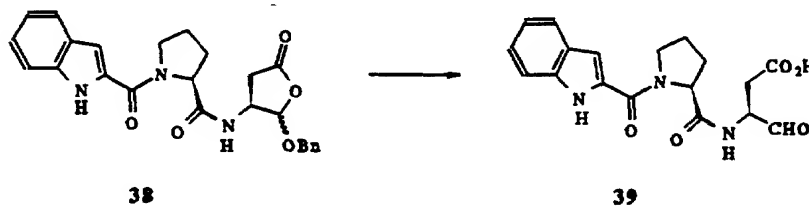
0908673-063101  
FOI290 E298960

Pyrrole-2-carboxylic acid (**34a**) (244mg, 2.2mmol) was added and the solution was cooled in an ice bath before the addition of *N,N*-diisopropylamine (0.78g, 6.0mmol), 1-hydroxybenzotriazole (0.54g, 4.0mmol) and ethyl dimethylaminopropyl carbodiimide hydrochloride (0.42g, 2.2mmol). The resulting mixture was stirred at 25°C for 17h and then saturated aqueous sodium chloride (30ml) was added. The mixture was extracted with ethyl acetate (3 x 20ml) and the combined organic extracts were washed with 5% aqueous sodium bicarbonate (3 x 10ml) and brine (10ml), dried (MgSO<sub>4</sub>) and concentrated. Flash chromatography (25% hexane-ethyl acetate) afforded 557mg (75%) of a 1:1 mixture of diastereomers as a white glassy solid: mp. 85-90°C; IR (KBr) 3288, 1789, 1665, 1629, 1557 and 1122; <sup>1</sup>H NMR(d<sub>6</sub>-DMSO) δ 11.46 (1H, bs), 8.55 (0.5H, d, *J*=7.0), 8.30 (0.5H, d, *J*=7.6), 8.06 (0.5H, d, *J*=7.0), 8.04 (0.5H, d, *J*=7.6), 7.36-7.30 (5H, m), 6.88-6.85 (2H, m), 6.10-6.07 (1H, m), 5.63 (0.5H, d, *J*=5.0), 5.42 (0.5H, s), 4.72 (2H, q, *J*=12.2), 4.74-4.25 (2H, m), 3.14-2.35 (2H, m), 1.29, 1.25 (3H, 2 x d, *J*=7.2).

(2*R,S*, 3*S*) *N*<sup>2</sup>-(5-Benzylpyrrole-2-carbonyl)-*N*-(tetrahydro-2-benzyloxy-5-oxo-3-furanyl)-*L*-alaninamide (**35b**), was prepared from 5-benzylpyrrole-2-carboxylic acid (**34b**) by the method described for compound **35a** (65%). Data is given for a single diastereomer. <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 11.37 (1H, brs), 8.27 (1H, d, *J*=7.4), 7.93 (1H, d, *J*=7.6), 7.33-7.16 (10H, m), 6.76 (1H, m), 5.82 (1H, m), 5.62 (1H, d, *J*=5.2), 4.76 (1H, d, *J*=12.0), 4.65 (1H, m), 4.62 (1H, d, *J*=12.2), 4.47 (1H, m), 3.88 (2H, s), 2.77 (1H, dd, *J*=9.0,18.0), 2.5 (dd), 1.23 (3H, d, *J*=7.0).

(3S) 3-[N-(Pyrrole-2-carbonyl)-L-alaninyl]amino-4-oxobutanoic acid (36a; D). A mixture of (35a) (612mg; 1.65mmol), methanol (40ml) and 10% palladium on carbon (500mg) was vigorously stirred under an atmosphere of hydrogen for 4h. The mixture was filtered through a 0.2 $\mu$ M nylon membrane then concentrated. The residue was purified by flash chromatography (5-10% methanol in methylene chloride) to afford the hemihydrate of (36a) (223mg, 48%) as a white solid after precipitation from an ethyl acetate-ether mixture. There were traces of solvent in the product: mp. 96-100°C; IR (KBr) 3381, 1774, 1729 (EtOAc), 1632, 1558, 1523, 1123; <sup>1</sup>H NMR(CD<sub>3</sub>OD)  $\delta$  6.94-6.85 (2H, m), 6.17 (1H, dd, *J*=3.8 and 2.6), 4.58 (0.5H, d, *J*=3.94), 4.56 (0.5H, d, *J*=4.24), 4.51 (1H, q, *J*=7.16), 4.35-4.20 (1H, m), 2.74-2.40 (2H, m), 1.42 and 1.41 (3H, 2 x d, *J*=7.13).

(3S) 3-[N-(5-Benzylpyrrole-2-carbonyl)-L-alaninyl]amino-4-oxobutanoic acid (36b), was prepared (41%) from 35b by the method described for compound 36a, to afford an off white solid: mp. 109-112°C; [ $\alpha$ ]<sub>D</sub><sup>25</sup> +6.3° (c 0.3, methanol); IR (KBr) 3368, 1724, 1630, 1530, 1453, 1414, 1233, 1049; <sup>1</sup>H NMR(d<sub>4</sub> methanol)  $\delta$  7.25-7.11 (5H, m), 6.76 (1H, d, *J*=3.5), 5.84 (1H, d, *J*=3.5), 4.51 (1H, m), 4.43 (1H, q, *J*=7.1), 4.23 (1H, m), 2.5 (2H, m), 1.35 (3H, d, *J*=7.0). Anal. Calcd for C<sub>19</sub>H<sub>21</sub>N<sub>3</sub>O<sub>5</sub> · 1.75 H<sub>2</sub>O: C, 56.64; H, 6.13; N, 10.43. Found: C, 56.34; H, 5.72; N, 10.00.



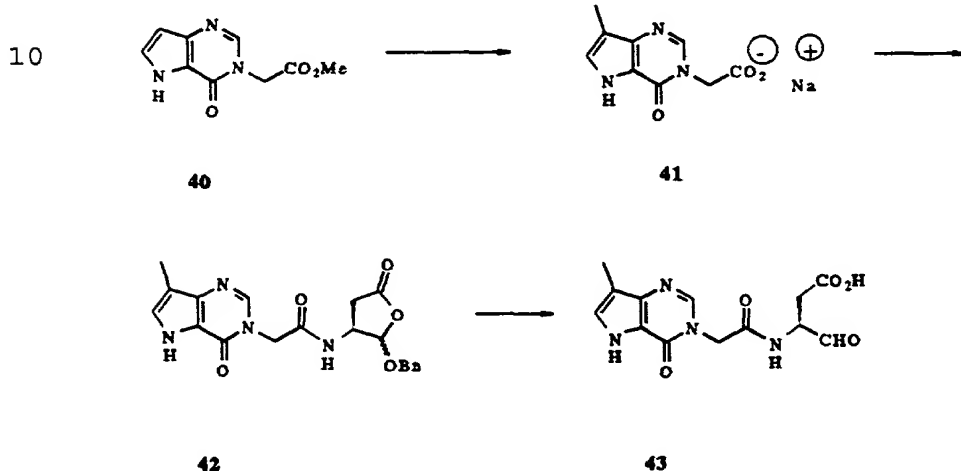


(2*R,S*, 3*S*) 1-(Indole-2-carbonyl)-N-(tetrahydro-2-benzyloxy-5-oxo-3-furanyl)-L-prolinamide (38).

Trifluoroacetic acid (4ml) was added to a solution of (2*R,S*, 3*S*) 1-tert-butoxycarbonyl-N-(tetrahydro-2-benzyloxy-5-oxo-3-furanyl)-L-prolinamide (15) (0.607g, 1.5mmol) in dichloromethane (4ml) at 0°C. The mixture was stirred at 0°C for 75 min. The mixture was concentrated, and the residue treated with diethyl ether, then the ether was removed under vacuum. This procedure was repeated twice to yield a yellow oil, which was dissolved in DMF (12ml). Diisopropylethylamine (0.78ml, 4.5mmol) followed by indole-2-carboxylic acid (266mg, 1.65mmol), 1-(3-dimethylaminopropyl)-3-ethyl carbodiimide hydrochloride (316mg, 1.65mmol) and hydroxybenzotriazole (405mg, 3mmol) were then added to the solution. The mixture was stirred at room temperature for 20h then poured into brine. The mixture was extracted with ethyl acetate (3 x 30ml). The combined organic extracts were washed with saturated aqueous sodium bicarbonate (2 x 60ml) then brine (2 x 60ml), dried (MgSO<sub>4</sub>), filtered and concentrated. The residue was purified by column chromatography (ethyl acetate) to afford 518mg (77%) of a mixture of diastereomers: IR (KBr) 3314, 1780, 1677, 1609, 1524, 1435, 1406, 1344; <sup>1</sup>H NMR (d<sub>6</sub>-DMSO), δ 11.58 (1H, m), 8.81-8.41 (1H, m), 7.71-6.67 (10H, m), 5.70 (d, *J*=5.2), 5.48 (s), 4.89-4.29 (4H, m), 3.99-3.74 (2H, m), 3.20-2.44 (2H, m), 2.39-1.77 (4H, m).

(3*S*) 3-[1-(Indole-2-carbonyl)-L-prolinyl]amino-4-oxobutanoic acid (39). A mixture of (2*R,S*, 3*S*) 1-(indole-2-carbonyl)-N-(tetrahydro-2-benzyloxy-5-oxo-3-furanyl)-L-prolinamide (38) (478mg, 1.07mmol) and 10% palladium on carbon (475mg) and methanol (150ml) was stirred under a hydrogen atmosphere for 6h. The

resulting mixture was filtered and concentrated to yield a colorless glass. Recrystallization from a mixture of methanol and diethyl ether afforded 202mg (53%) of a colorless solid: mp. 135-138°C;  $[\alpha]_D^{24}$  -44° (c 0.25, CH<sub>3</sub>OH); IR (KBr) 3287, 2977, 2879, 1781, 1725, 1716, 1667, 1662, 1600, 1529, 1441, 1346; <sup>1</sup>H NMR(CD<sub>3</sub>OD) δ 7.65 (1H, d, J=8.0), 7.44 (1H, d, J=8.4), 7.22 (1H, m), 7.09-6.84 (2H, m), 4.62 (2H, m), 4.29 (1H, m), 4.15-3.73 (2H, m), 2.74-1.72 (6H, m).



Methyl 2-(3,5-dihydro-7-methyl-4-oxo-4H-pyrrolo [3,2-d] pyrimidin-3-yl)acetate (40). Freshly prepared methyl glycinate (1.25g, 14mmol) was added to a stirred solution of ethyl 3-[N-(dimethylamino) methylene]amino-4-methylpyrrole-2-carboxylate (1.56g, 7.0mmol; Lim et al., *J. Org. Chem.*, 44, pp. 3826-29 (1979)) in dry methanol (60ml). The resulting mixture was kept at 70°C. Two further batches of methyl glycinate (1.25, 14.0mmol) were added after 18h and 42h heating. The mixture was cooled and filtered 24h after the final addition. The filtrate was concentrated and the residue purified by flash chromatography (2-5%

methanol/chloroform) to afford 0.54g (35%) of a white crystalline solid: mp. 233-235°C (recrystallized from ethyl acetate); IR (KBr) 3135, 2958, 1745, 1675, 1254; <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 11.90 (1H, s), 8.07 (1H, s), 7.23 (1H, s), 4.83 (2H, s), 3.69 (3H, s), 2.16 (3H, s).  
Anal. Calcd for C<sub>10</sub>H<sub>11</sub>N<sub>3</sub>O<sub>3</sub> · 0.1H<sub>2</sub>O: C, 53.85; H, 5.07; N, 18.84. Found: C, 53.85; H, 4.96; N, 18.81; MS(70eV.E.I.) m/e 222, 221 (M<sup>+</sup>, 100%), 189, 162, 133, 105.

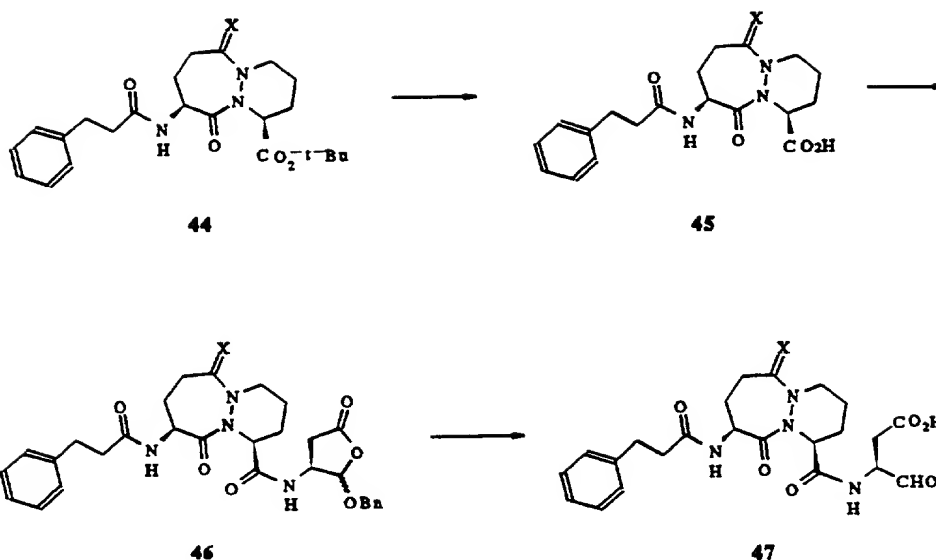
2-(3,5-Dihydro-7-methyl-4-oxo-4H-pyrrolo[3,2-d]pyrimidin-3-yl)acetic acid, sodium salt (41). A suspension of 40 (354mg, 1.6mmol) in methanol (15ml) was treated with 0.5N sodium hydroxide (4.8ml) and the resulting mixture was stirred at 25°C for 1h. The reaction mixture was filtered to afford the hemihydrate of 41 (354mg, 97%) as a white crystalline solid : mp. >340°C (recrystallized from methanol); IR (KBr) 3461, 3143, 1676, 1666, 1605, 1415; <sup>1</sup>H NMR(d<sub>6</sub> DMSO) δ 11.63 (1H, s), 7.83 (1H, s), 7.11 (1H, d, J=2.0), 4.24 (2H, s), 2.14 (3H, s). Anal. Calcd for C<sub>9</sub>H<sub>8</sub>N<sub>3</sub>O<sub>3</sub>Na · 0.5H<sub>2</sub>O: C, 45.39; H, 3.81; N, 17.64. Found: C, 45.57; H, 4.05; N, 17.39.

(2*R,S*, 3*S*) 2-(3,5-Dihydro-7-methyl-4-oxo-4H-pyrrolo[3,2-d]pyrimidin-3-yl)-N-(tetrahydro-2-benzyloxy-5-oxo-3-furanyl)acetamide (42). A suspension of the sodium salt 41 (344mg, 1.5mmol) in dry DMF (15ml) was treated with ethyl dimethylaminopropyl carbodiimide hydrochloride (373mg, 1.95mmol) and 1-hydroxybenzo-triazole (405mg, 3.0mmol). The mixture was kept at 25°C for 1h then (2*R,S*, 3*S*) N-allyloxycarbonyl-3-amino-2-benzyloxy-5-oxotetrahydrofuran (437mg, 1.5mmol; Chapman, Bioorg. Med. Chem. Lett., 2, pp. 613-18 (1992)) and (Ph<sub>3</sub>P)<sub>2</sub>PdCl<sub>2</sub>

(25mg) were added followed by the dropwise addition of n-tributyltin hydride (0.6ml, 2.25mmol). The resulting mixture was stirred at 25°C for 1h then water (20ml) was added. The mixture was extracted with ethyl acetate (3 x 15ml), and the combined organic extracts were washed with water (5ml), dried (MgSO<sub>4</sub>), and concentrated to afford a mixture of diastereomers. Evaporation of the aqueous phase and purification of the residue by flash chromatography (5% methanol/chloroform) gave an additional quantity affording a total 182mg of **42** (31%) : m.p. 240-244°C; IR (KBr) 3274, 1772, 1691, 1664, 1562; <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 11.81 (1H, s), 8.85 (0.6H, d, J=6.6), 8.72 (0.4H, d, J=7.4), 7.98 (0.6H, s), 7.95 (0.4H, s), 7.40-7.30 (5H, m), 7.20 (1H, d, J=2.2), 5.61 (0.4H, d, J=5.0), 5.46 (s), 4.85-4.60 (m), 4.28 (m), 3.20-2.35 (2H, m), 2.16 (3H, s).

**(3S)-3-[2-(3,5-Dihydro-7-methyl-4-oxo-4H-pyrrolo[3,2-d]pyrimidin-3-yl)-1-oxo-ethylamino]-4-oxobutanoic acid (43)**. A mixture of **42** (131mg, 0.33mmol), in methanol (50ml) and 10% palladium on carbon (100mg) was stirred vigorously under an atmosphere of hydrogen for 2h. An additional quantity of catalyst (100mg) was added and the mixture hydrogenated for a further 2h. The mixture was filtered through a 0.2μM nylon membrane, and concentrated. The residue was recrystallized from methanol/diethyl ether to afford 79mg (78%) of **43** as a hygroscopic white solid: mp. 222-226°C; (decomp.); [α]<sub>D</sub><sup>32</sup> +0.5 (c 0.02, MeOH); IR (KBr) 3282, 1680, 1558, 1425 1275; <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 8.03 (1H, s), 7.18 (1H, d, J=0.7), 4.79-4.74 (2H, m), 4.63-4.59 (1H, 2 x d, J=3.6), 4.36-4.25 (1H, m), 2.78-2.39 (2H, m), 2.24 (3H, d, J=0.7). Anal. Calcd for C<sub>13</sub>H<sub>14</sub>N<sub>4</sub>O<sub>5</sub> · 1.4H<sub>2</sub>O: C, 47.10; H, 5.12; N, 16.90. Found: C, 47.00; H, 4.79; N, 16.59.

FABMS m/e 307, 306 (M<sup>+</sup>), 244, 207, 190, 152, 115 (100%).



- (a) X = O  
(b) X = H<sub>2</sub>

5 (1*S*,9*S*) t-Butyl 6,10-dioxo-octahydro-9-(3-phenylpropionylamino)-6H-pyridazino[1,2-a]  
[1,2]diazepine-1-carboxylate (44a). To a solution of  
(1*S*,9*S*)t-butyl 9-amino-6,10-dioxo-octahydro-6H-  
pyridazino [1,2-a] [1,2]diazepine-1-carboxylate (690mg;  
10 2.32mmol; GB 2128984) in dioxane (16ml) and water (4ml)  
at 0°C was added solid sodium bicarbonate (292mg;  
3.48mmol) followed by dropwise addition of 3-  
phenylpropionyl chloride (470mg; 2.78mmol). The  
mixture was stirred at room temperature for 2h then  
15 more sodium bicarbonate (200mg; 2.38mmol) and 3-  
phenylpropionyl chloride (100mg; 0.6mmol) was added.  
The mixture was stirred for a further 2h at room  
temperature, diluted with ethyl acetate (50ml), washed

with saturated sodium bicarbonate (2 x 25ml) then dried  
(MgSO<sub>4</sub>) and concentrated. The residue was purified by  
flash chromatography (0-50% ethyl acetate/chloroform)  
and finally crystallized by trituration with ether to  
5 afford 860mg (86%) of a white solid: mp. 137-138°C;  
[α]<sub>D</sub><sup>23</sup> -95.1° (c 0.549, CH<sub>2</sub>Cl<sub>2</sub>); IR (KBr) 3327, 1736,  
1677, 1664, 1536, 1422, 1156; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.24 (5H,  
m), 6.50 (1H, d, J=7.5), 5.24 (1H, m), 4.90 (1H, m),  
4.60 (1H, m), 3.44 (1H, m), 2.93 (2H, m), 2.84 (1H, m),  
10 2.64 (1H, m), 2.54 (2H, m), 2.26 (2H, m), 1.70 (4H, m),  
1.70 (9H, s). MS(FAB, m/z): 430 (M<sup>+</sup> + 1), 374, 242,  
105, 91.

(1S,9S)-t-Butyl octahydro-10-oxo-9-(3-  
phenylpropionylamino)-6H-pyridazino-[1,2-a]  
15 [1,2]diazepine-1-carboxylate (44b), was prepared from  
(1S, 9S)-t-butyl 9-amino-octahydro-10-oxo-6H-  
pyridazino[1,2-a][1,2]diazepine-1-carboxylate (Attwood  
et al., J. Chem. Soc. Perkin 1, pp. 1011-19 (1986)) as  
for 44a, to afford 810mg (81%) of a colorless oil:  
20 [α]<sub>D</sub><sup>23</sup> - 33.5° (c 0.545, CH<sub>2</sub>Cl<sub>2</sub>); IR (film) 3334, 2935,  
1737, 1728, 1659, 1642; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.24 (5H, m),  
6.75 (1H, d, J=6.7), 5.27 (1H, m), 4.92 (1H, m), 3.39  
(1H, m), 3.03 (4H, m), 2.55 (3H, m), 2.33 (1H, m), 2.17  
(1H, m), 1.80 (5H, m), 1.47 (9H, s), 1.39 (1H, m).  
25 MS(FAB, m/z): 416 (M<sup>+</sup> + 1), 360, 211, 143, 97.

(1S,9S) 6,10-Dioxo-octahydro-9-(3-  
phenylpropionylamino)-6H-pyridazino[1,2-a]  
[1,2]diazepine-1-carboxylic acid (45a). To a solution  
of (1S,9S) t-butyl 6,10-dioxo-octahydro-9-(3-  
30 phenylpropionylamino)-6H-pyridazino[1,2-a]  
[1,2]diazepine-1-carboxylate (44a) (800mg; 1.863mmol)  
in dry dichloromethane (5ml) at 0°C was added  
trifluoroacetic acid (5ml). The solution was stirred

at room temperature for 3h then concentrated. Dry ether (10ml) was added to the residue then removed under vacuum. This process was repeated three times to afford a crystalline solid. The solid was triturated with ether and filtered to afford 590mg (85%) of a white crystalline solid: mp. 196-197.5°C;  $[\alpha]_D^{23}$  -129.5° (c 0.2, CH<sub>3</sub>OH); IR (KBr) 3237, 1729, 1688, 1660, 1633, 1574, 1432, 1285, 1205; <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 8.28 (1H, d, J=7.4), 7.22 (5H, m), 5.32 (1H, dd, J=5.9, 2.9), 4.75 (1H, m), 4.51 (1H, m), 3.50 (1H, m), 3.01 (1H, m), 2.91 (2H, m), 2.55 (2H, m), 2.29 (3H, m), 1.95 (2H, m), 1.71 (2H, m). Anal. Calcd for C<sub>19</sub>H<sub>23</sub>N<sub>3</sub>O<sub>5</sub>: C, 61.12; H, 6.21; N, 11.25. Found: C, 60.80; H, 6.28; N, 10.97. MS(FAB, m/z) 374 (M<sup>+</sup> + 1), 242, 105, 91.

(1*S*, 9*S*) Octahydro-10-oxo-9-(3-phenylpropionylamino)-6H-pyridazino[1,2-*a*]-[1,2]diazepine-1-carboxylic acid (45b), was prepared from (1*S*, 9*S*) t-butyl octahydro-10-oxo-9-(3-phenylpropionylamino)-6H-pyridazino[1,2-*a*][1,2]diazepine-1-carboxylate (44b) by the method described for compound 45a to afford 657mg (96%) of 45b as a crystalline solid: mp. 198-202°C;  $[\alpha]_D^{23}$  -86.2° (c 0.5, CH<sub>3</sub>OH); IR (KBr) 3294, 2939, 1729, 1645, 1620, 1574, 1453, 1214; <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 7.92 (1H, d, J=7.9), 7.20 (5H, m), 5.29 (1H, m), 4.90 (1H, m), 3.47 (1H, m), 3.08 (2H, m), 2.90 (2H, m), 2.55 (3H, m), 2.36 (1H, m), 1.81 (5H, m), 1.43 (2H, m). MS(FAB, m/z) 360 (M<sup>+</sup> +1), 211, 143, 91.

[3*S*, 2*R*, *S*, (1*S*, 9*S*)] N-(2-Benzoyloxy-5-oxotetrahydrofuran-3-yl)-6,10-dioxo-octahydro-9-(3-phenylpropionylamino)-6H-pyridazino[1,2-*a*][1,2]diazepine-1-carboxamide (46a). To a solution of (1*S*, 9*S*) 6,10-dioxo-octahydro-9-(3-phenyl-propionylamino)-6H-pyridazino[1,2-*a*][1,2]diazepine-1-carboxylic acid (45a) (662mg;

1.773mmol) in dry dichloromethane (9ml) and dry dimethyl formamide (3ml) at room temperature was added bis(triphenylphosphine)palladium chloride (30mg) and (3*S*, 2*R*,*S*)-3-allyloxycarbonylamino-2-benzyloxy-5-oxotetrahydrofuran (Chapman, Bior. Med. Chem. Lett., 2, pp. 613-18 (1992)) (568mg; 1.95mmol) followed by dropwise addition of tri-*n*-butyltin hydride (1.19g; 4.09mmol). 1-Hydroxy-benzotriazole (479mg; 3.546mmol) was added to the mixture and the mixture was cooled to 0°C before addition of 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride (408mg; 2.128mmol). The mixture was stirred at room temperature for 3.25h then diluted with ethyl acetate (50ml), washed twice with dilute hydrochloric acid (20ml), twice with saturated sodium bicarbonate (20ml), once with brine then dried (MgSO<sub>4</sub>) and concentrated. The resulting oil was purified by flash chromatography (0-100% ethyl acetate/chloroform) to afford 810mg (81%) of **46a** as a mixture of anomers: mp. 92-94°C; IR (KBr) 3311, 1791, 1659, 1651, 1536; <sup>1</sup>H NMR(CDCl<sub>3</sub>) δ 7.49, 6.56 (1H, 2d, *J*=6.7, 7.8), 7.29 (10H, m), 6.37, 6.18 (1H, 2d, *J*=7.7, 7.6), 5.56, 5.34 (1H, d, s, *J*=5.2), 5.08-4.47 (6H), 3.18-2.80 (5H), 2.62-2.28 (5H), 2.04-1.53 (5H). MS(FAB, *m/z*), 563 (*M*<sup>+</sup> + 1), 328, 149, 91.

**[3*S*, 2*R*,*S*, (1*S*, 9*S*)] N-(2-Benzyloxy-5-oxotetrahydrofuran-3-yl)-octahydro-10-oxo-9-(3-phenylpropionylamino)-6H-pyridazino[1,2-*a*][1,2]diazepine-1-carboxamide (46b)**, was prepared from **45b** by the method described for **46a** to yield 790mg (96%) of a glass: m.p. 58-60°C; IR (KBr) 3316, 2940, 1793, 1678, 1641, 1523, 1453, 1120; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.28 (10H, m), 6.52, 6.42 (1H, 2d, *J*=7.2, 7.1), 5.53, 5.44 (1H, d, s, *J*=5.2), 5.35 (1H, m), 4.6-4.9, 4.34 (4H, m), 3.1-2.8 (6H, m), 2.6-2.1 (7H), 1.95-1.05 (5H).



MS(FAB, m/z), 549 ( $M^+ + 1$ ), 400, 310, 279, 91.

[3*S*, (1*S*, 9*S*)] 3-(6,10-Dioxo-octahydro-9-(3-phenylpropionylamino)-6H-pyridazino[1,2-*a*][1,2]diazepine-1-carboxamido)-4-oxobutanoic acid (47a).

5 A mixture of [3*S*, 2*R*,*S*, (1*S*, 9*S*)] N-(2-benzyloxy-5-oxotetrahydrofuran-3-yl)-6,10-dioxo-octahydro-9-(3-phenylpropionylamino)-6H-pyridazino[1,2-*a*][1,2]diazepine-1-carboxamide (46a) (205mg; 0.364mmol), 10% palladium on carbon (200mg) and methanol (20ml) was  
10 stirred under hydrogen at atmospheric pressure for 5h. The mixture was filtered then concentrated to yield 154mg (90%) of a glass: mp. 116-118°C;  $[\alpha]_D^{23}$  -140° (c 0.1, CH<sub>3</sub>OH); IR (KBr) 3323 (br), 1783, 1731, 1658, 1539, 1455, 1425; <sup>1</sup>H NMR (CD<sub>3</sub>OD)  $\delta$  7.21 (5H, m), 5.17 (1H, m), 4.73 (1H, m), 4.50 (2H, m), 4.23 (1H, m), 3.38 (1H, m), 3.06 (1H, m), 2.91 (2H, m), 2.73-2.18 (6H, m) and 2.01-1.59 (5H, m). Anal. Calcd for C<sub>23</sub>H<sub>27</sub>N<sub>4</sub>O<sub>7</sub> + H<sub>2</sub>O : C, 56.32; H, 6.16; N, 11.42. Found: C, 56.29; H, 6.11; N, 11.25. MS(FAB, m/z) 473 ( $M^+ + 1$ ), 176, 149, 105, 91.

20 [3*S*, (1*S*, 9*S*)] 3-(Octahydro-10-oxo-9-(3-phenylpropionylamino)-6H-pyridazino-[1,2-*a*][1,2]diazepine-1-carboxamido)-4-oxobutanoic acid (47b), was prepared from 46b by the method described for 47a. The residue was purified by flash chromatography (0-10%  
25 methanol/chloroform) to afford 65mg (52%) of a glass; m.p. 87-90°C;  $[\alpha]_D^{23}$  -167.0° (c 0.1, methanol); IR (KBr) 3329, 2936, 1786, 1727, 1637; <sup>1</sup>H NMR (CD<sub>3</sub>OD)  $\delta$  7.23 (5H, m), 5.29 (1H, m), 4.83 (1H, m), 4.59 (1H, d, *J*=3.6), 4.29 (1H, m), 3.3-3.0 (3H, m), 2.91 (2H, m), 2.70-2.34 (5H, m), 2.19 (2H, m), 1.75 (4H, m), 1.36 (2H, m). Anal. Calcd for C<sub>23</sub>H<sub>30</sub>N<sub>4</sub>O<sub>6</sub> + 0.5H<sub>2</sub>O: C, 59.09; H, 6.68; N, 11.98. Found: C, 58.97; 6.68; N, 11.73.  
30 MS(FAB, m/z) 459 ( $M^+ + 1$ ), 310, 149, 105, 91.



	$R_1$	$R_2$	$R_3$
	(a) $\text{PhCH}_2$	H	(S) Me
	(b) $\text{PhCH}_2$	$\text{CH}_2\text{Ph}$	H
5	(c) $\text{PhCH}_2$	$(\text{CH}_2)_2\text{Ph}$	H
	(d) $\text{PhCH}_2$	nBu	H
	(e) $\text{PhCH}_2$	Me	H
	(f) $\text{PhCH}_2$	Ph	H
	(g) $\text{PhCH}_2$	H	H
10	(h) $\text{PhCH}_2$	$\text{CH}_2\text{Ph}$	(S) -Me
	(i) $\text{Ph}(\text{CH}_2)_2$	$\text{CH}_2\text{Ph}$	H

Pyridones **48** were prepared by the method described by Damewood et al., J. Med. Chem., 37, pp. 3303-12 (1994)). Compound **48d** is new.

**3-Benzoyloxycarbonylamino-6-butyl-pyrid-2-one (48d)**, was isolated as a cream solid: mp. 158-160°C; IR (KBr) 3382, 2953, 2930, 2866, 1729, 1643, 1524, 1468, 1202, 1044;  $^1\text{H}$  NMR ( $\text{d}_6$ -DMSO)  $\delta$  8.26 (1H, s), 7.72 (1H, d), 7.39 (5H, m), 6.00 (1H, d), 5.14 (2H, s), 2.41 (2H, t), 1.52 (2H, m), 1.24 (2H, m), 0.87 (3H, t). Anal. Calcd for  $\text{C}_{17}\text{H}_{20}\text{N}_2\text{O}_3$ : C, 67.98; H, 6.71; N, 9.33. Found: C, 67.69; H, 6.68; N, 9.20. MS CI  $\text{M}^+ = 300$  (m) 28%.

**(2S) Methyl 2-[3-benzyloxycarbonylamino-1,2-dihydro-2-oxo-1-pyridyl]propionate (49a)**. Sodium hydride (80% oil dispersion) (0.35g, 11.64mmole) was added to a stirred mixture of 3-(benzyloxycarbonylamino)pyrid-2-

one (48a) (2.58g, 10.58mmol) and tetrahydrofuran (100ml) at room temperature. The mixture was stirred for 10 mins. The resulting solution was added to a solution of 2(R) methyl-2((trifluoromethane) sulphonyloxy)propionate (2.5g, 10.58mmole; Feenstra et al., Tetrahedron Lett., 28, pp. 1215-18 (1987)) in tetrahydrofuran (5ml) at room temperature during 10 mins. The mixture was stirred at room temperature for 80 mins then poured into ethyl acetate. The mixture was washed twice with 1M HCl, twice with aqueous sodium bicarbonate then brine. It was dried (MgSO<sub>4</sub>) and concentrated. The residue was purified by flash chromatography (30% ethyl acetate/hexane) to afford 2.945g (84%) of a colorless solid: mp. 96-7°;  $[\alpha]_D^{20}$  - 71.36 (c 2.5, CHCl<sub>2</sub>); IR (KBr) 3370, 1764, 1729, 1648, 1602, 1564, 1523, 1515, 1503, 1449, 1359, 1203, 1064; <sup>1</sup>H NMR(CDCl<sub>3</sub>) δ 8.04 (1H, d, J=7.2), 7.86 (1H, s), 7.36 (5H, m), 6.98 (1H, dd, J=7.1, J=1.7), 6.30 (1H, t, J=7.2), 5.46 (1H, q, J=7.4), 5.20 (2H, s), 3.74 (3H, s), 1.66 (3H, d, J=7.4). Anal. Calcd for C<sub>17</sub>H<sub>18</sub>N<sub>2</sub>O<sub>5</sub>: C, 61.81; H, 5.49; N, 8.48. Found: C, 61.49; H, 5.51; N, 8.41. MS(FAB, m/z) 331 (M<sup>+</sup> + 1), 299, 223, 196, 163, 91.

**Methyl [6-benzyl-3-benzyloxycarbonylamino-1,2-dihydro-2-oxo-1-pyridyl]-acetate (49b).** Sodium hydride (80% oil dispersion) (0.65g, 26.2mmole) was added to a stirred mixture of 6-benzyl-3(benzyloxycarbonylamino)pyrid-2-one (48b) (7.3g, 2.18mmol) and tetrahydrofuran (150ml) at room temperature. The mixture was stirred for 10mins, treated with methyl bromoacetate (2.5ml, 26.2mmol) and kept for 3h. The resulting mixture was poured onto a mixture of ice and 1M HCl. The resulting solid was filtered off then dissolved in dichloromethane. The resulting solution was dried

(MgSO<sub>4</sub>), decolourized with charcoal and concentrated. The residue was purified by chromatography (2-5% ethyl acetate/dichloromethane) to afford 7.2g (81%) of colorless crystals: mp. 117-9°; IR (KBr) 3375, 1753, 1730, 1651, 1605, 1513, 1384, 1223, 1185, 1071; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 8.02 (1H, d, J=7.5), 7.78 (1H, s), 7.31 (8H, m), 7.10 (2H, m), 6.15 (1H, d, J=7.5), 5.20 (2H, s), 4.70 (2H, s), 3.88 (2H, s), 3.66 (3H, s).

The following compounds were prepared in a similar manner:

**Methyl [3-benzyloxycarbonylamino-1,2-dihydro-2-oxo-6-phenethyl-1-pyridyl]-acetate (49c).** 97% yield: m.p. 102-4°C. IR (KBr) 3245, 3232, 1741, 1725, 1648, 1600, 1526, 1216; <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 8.45 (1H, s), 7.76 (1H, d, J = 7.6), 7.35 (10H, m), 6.15 (1H, d, J = 7.6), 5.15 (2H, s), 4.85 (2H, s), 3.68 (3H, s), 2.86 (4H, s).

**Methyl [3-benzyloxycarbonylamino-6-butyl-1,2-dihydro-2-oxo-1-pyridyl]-acetate (49d).** 90% yield: mp. 111-112°C; IR (KBr) 3393, 1738, 1731, 1645, 1598, 1517, 1225, 1208; <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 8.39 (1H, s), 7.78 (1H, d, J = 7.7), 7.35 (5H, m), 6.17 (1H, d, J = 7.7), 5.15 (2H, s), 4.80 (2H, s), 3.67 (3H, s), 1.38 (6H, m), 0.89 (3H, t).

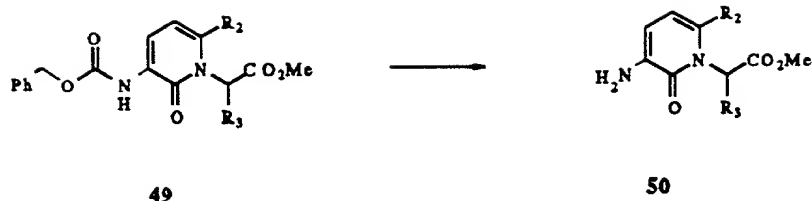
**Methyl [3-benzyloxycarbonylamino-1,2-dihydro-6-methyl-2-oxo-1-pyridyl]-acetate (49e).** 84% yield as a colorless solid: mp. 115-6°C; IR (KBr) 3246, 1740, 1725, 1649, 1598, 1573, 1535, 1417, 1365, 1259, 1219, 1193, 1090, 1068, 1006; <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 8.40 (1H, s), 7.75 (1H, d, J = 7.6), 7.38 (5H, m), 6.20 (1H, d, J = 7.6), 5.15 (2H, s), 4.85 (2H, s), 3.68 (3H, s), 2.26 (3H, s).

**Methyl [3-benzyloxycarbonylamino-1,2-dihydro-6-phenyl-1-pyridyl]-acetate (49f).** 67% yield as a colorless oil: IR (KBr) 3266, 1739, 1727, 1646, 1606, 1566, 1517, 1490, 1365, 1213, 1163, 1075; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 8.15 (1H, d), 7.85 (1H, s), 7.39 (10H, m), 6.22 (1H, d), 5.22 (2H, s), 4.57 (2H, s), 3.74 (3H, s).

**Methyl [3-benzyloxycarbonylamino-1,2-dihydro-2-oxo-1-pyridyl]-acetate (49g).** 80% yield as a colorless crystalline solid: m.p. 110-111°C. IR (KBr) 3385, 1745, 1726, 1650, 1601, 1512, 1502, 1378, 1369, 1358, 1215, 1195, 1162, 1067; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 8.06 (1H, d), 7.84 (1H, s), 7.36 (5H, m), 6.88 (1H, dd), 6.27 (1H, t), 5.20 (2H, s), 4.68 (2H, s), 3.78 (3H, s). Anal. Calcd for C<sub>16</sub>H<sub>16</sub>N<sub>2</sub>O<sub>5</sub>: C, 60.75; H, 5.10; N, 8.85. Found: C, 60.65; H, 5.15; N, 8.85. MS FAB (+)M<sup>+</sup> = 317 (M + 1).

**2(S) Methyl 2-methyl-[6-benzyl-(3-benzyloxycarbonylamino)-1,2-dihydro-2-oxo-1-pyridyl]-acetate (49h),** was prepared by the method used in the preparation of compound **49a** to afford (58%) an oil; [α]<sub>D</sub><sup>25</sup> -25.0° (c 1, CH<sub>2</sub>Cl<sub>2</sub>); IR (KBr) 3381, 1736, 1650, 1604, 1513, 1218, 1190, 1068; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.97 (1H, d), 7.78 (1H, s), 7.4-7.14 (10H, m), 6.17 (1H, d), 5.19 (2H, s), 4.64 (1H, q), 3.98 (2H, s), 3.62 (3H, s), 1.31 (3H, d).

**Methyl [6-benzyl-1,2-dihydro-2-oxo-3-(2-phenylethoxy)-carbonylamino-1-pyridyl]acetate (49i),** was isolated (88%) as a colorless solid: mp. 130-133°C; IR (KBr) 3363, 1746, 1732, 1651, 1604, 1515, 1368, 1231, 1212, 1185; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 8.00 (1H, d, J = 7.0), 7.68 (1H, s), 7.36-7.10 (10H, m), 6.15 (1H, d, J = 7.6), 4.7 (2H, s), 4.38 (2H, t, J = 7.0), 3.88 (2H, s), 3.67 (3H, s), 2.98 (2H, t, J = 7).



2(*S*) Methyl 2[3-amino-1,2-dihydro-2-oxo-1-pyridyl]propionate (50a). A mixture of 2(*S*) methyl-2[3-benzyloxycarbonylamino-1,2-dihydro-2-oxo-1-pyridyl]propionate (49a) (2.75g, 8.33mmol), methanol (100ml), and 10% palladium on carbon (300mg) was stirred under an atmosphere of hydrogen for 30min. The mixture was filtered and concentrated to afford 1.63g (100%) of a colorless solid: <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 8.35 (1H, brs), 7.46 (1H, d), 7.22 (1H, d), 6.29 (1H, t), 5.22 (1H, q), 3.63 (3H, s), 1.55 (3H, d).

The following compounds were prepared in a similar manner:

15 Methyl [3-amino-6-benzyl-1,2-dihydro-2-oxo-1-pyridyl]acetate (50b). 100% yield as a grey solid: mp. 134-6°C; IR (KBr) 3418, 3312, 1723, 1658, 1596, 1548, 1435, 1290, 1245, 1011; <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 7.25 (5H, m), 6.45 (1H, d, *J* = 7.4), 5.92 (1H, d, *J* = 7.4), 5.00 (2H, s), 4.63 (2H, s), 3.88 (2H, s), 3.51 (3H, s).

25 Methyl[3-amino-1,2-dihydro-2-oxo-6-phenethyl-1-pyridyl]acetate (50c). 99% yield as a viscous oil: IR (KBr) 3456, 341, 2953, 1745, 1649, 1600, 1548, 1219; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.25 (5H, m), 6.51 (1H, d, *J* = 7.4), 5.92 (1H, d, *J* = 7.4), 4.79 (2H, s), 3.77 (3H, s), 2.80 (4H, m).

Methyl[3-amino-6-butyl-1,2-dihydro-2-oxo-1-pyridyl]acetate (50d). 97% as a brown solid: mp. 75-7°C; IR (KBr) 3437, 3342, 2955, 1745, 1655, 1609, 1550, 1432, 1301, 1222, 1200; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 6.53 (1H, d, *J* = 6.8), 5.93 (1H, d, *J* = 6.8), 4.81 (2H, s), 3.77 (3H, s), 2.44 (2H, t), 1.45 (4H, m), 0.93 (3H, t).

Methyl[3-amino-1,2-dihydro-6-methyl-2-oxo-1-pyridyl]acetate (50e), was isolated (100%) as a colorless crystalline solid: mp. 87-9°C; IR (KBr) 3442, 3326, 1735, 1647, 1600, 1549, 1434, 1407, 1383, 1366, 1225, 1209; <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 6.40 (1H, d, *J* = 7.3), 5.93 (1H, d, *J* = 7.3), 4.86 (2H, s), 4.79 (2H, s), 3.67 (3H, s), 2.15 (3H, s).

Methyl[3-amino-1,2-dihydro-2-oxo-6-phenyl-1-pyridyl]acetate (50f), was isolated (86%) as a grey solid: mp. 207-9°C; IR (KBr) 3473, 3345, 1750, 1644, 1600, 1536, 1443, 1366, 1309, 1212, 1184, 1156; <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 7.30 (5H, m), 6.54 (1H, d), 6.03 (1H, d), 5.25 (2H, s), 4.49 (2H, s), 3.61 (3H, s).

Methyl[3-amino-1,2-dihydro-2-oxo-1-pyridyl]acetate (50g), was obtained as a colorless oil and used immediately in the next step.

2(S) Methyl 2-methyl-[3-amino-6-benzyl-1,2-dihydro-2-oxo-1-pyridyl]acetate (50h), was isolated (69%) as a colorless oil: IR (film) 3354, 1743, 1646, 1600, 1548, 1494, 1455, 1309, 1268, 1227, 1113; <sup>1</sup>H NMR (C<sub>6</sub>D<sub>6</sub>) δ 7.29-6.76 (5H, m), 5.86 (1H, d, *J* = 7.2), 5.51 (1H, d, *J* = 7.2), 4.43 (1H, q, *J* = 6.7), 3.69 (2H, s), 3.41 (2H, s), 3.36 (3H, s), 1.43 (3H, d, *J* = 6.7).



	$R_1$	$R_2$	$R_3$
	(a) $\text{Ph}(\text{CH}_2)_2\text{CO}$	H	(S)Me
	(b) $\text{Ph}(\text{CH}_2)_2\text{CO}$	$\text{CH}_2\text{Ph}$	H
5	(c) $\text{Ph}(\text{CH}_2)_2\text{CO}$	$(\text{CH}_2)_2\text{Ph}$	H
	(d) $\text{Ph}(\text{CH}_2)_2\text{CO}$	nBu	H
	(e) $\text{Ph}(\text{CH}_2)_2\text{CO}$	Me	H
	(f) $\text{Ph}(\text{CH}_2)_2\text{CO}$	Ph	H
	(g) $\text{Ph}(\text{CH}_2)_2\text{CO}$	H	H
10	(h) $\text{Ph}(\text{CH}_2)_2\text{CO}$	$\text{CH}_2\text{Ph}$	(S)-Me or (R,S)-Me
	(i) AcTyr	$\text{CH}_2\text{Ph}$	H
	(j) $\text{Ph}(\text{CH}_2)_2\text{SO}_2$	$\text{CH}_2\text{Ph}$	H
	(k) $\text{Ph}(\text{CH}_2)_2\text{OCO}$	$\text{CH}_2\text{Ph}$	H
15	(l) $\text{Ph}(\text{CH}_2)_3\text{CO}$	$\text{CH}_2\text{Ph}$	H

**2(S) Methyl 2-[1,2-dihydro-2-oxo-3-(3-phenylpropionyl) amino-1-pyridyl]- propionate (51a).** 3-Phenylpropionyl chloride (1.5g, 9mmol) was added dropwise to a stirred mixture of 2S methyl-2-[3-amino-1,2-dihydro-2-oxo-1-pyridyl]propionate (**50a**) (1.63g, 8.33mmol), dioxane (60ml), water (15ml) and sodium bicarbonate (1.54g, 16.7mmol). The mixture was kept for 1h then extracted with ethyl acetate. The extracts were washed with aqueous sodium bicarbonate, dried ( $\text{MgSO}_4$ ) and concentrated. The resulting red oil was purified by flash chromatography to afford 2.54g (93%) of an oil:



[ $\alpha$ ]<sub>D</sub><sup>20</sup> -68°C (1, CH<sub>2</sub>Cl<sub>2</sub>); IR (CH<sub>2</sub>Cl<sub>2</sub>) 3369, 1747, 1690, 1650, 1602, 1512, 1267, 1260, 1217; <sup>1</sup>H NMR (CDCl<sub>3</sub>)  $\delta$  8.41 (1H, dd), 8.36 (1H, s), 7.24 (5H, m), 7.02 (1H, dd), 6.32 (1H, t), 5.44 (1H, q), 3.75 (3H, s), 3.03 (2H, t), 2.70 (2H, t), 1.66 (3H, d). FAB M<sup>+</sup> = 329 (M + 1), 197, 165, 131, 110, 91.

The following compounds were prepared in a similar manner:

**Methyl [6-benzyl-1,2-dihydro-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl]-acetate (51b)**, was isolated (93%) as crystals: mp. 95-7°C; IR (KBr) 3265, 1747, 1686, 1642, 1590, 1563, 1511, 1454, 1401, 1220, 1183, 1133; <sup>1</sup>H NMR (CDCl<sub>3</sub>)  $\delta$  8.39 (1H, d, *J* = 7.7), 8.27 (1H, s), 7.21 (10H, m), 6.17 (1H, d, *J* = 7.7), 4.70 (2H, s), 3.89 (2H, s), 3.67 (3H, s), 3.02 (2H, m), 2.70 (2H, m).

**Methyl [1,2-dihydro-2-oxo-6-phenethyl-3-(3-phenylpropionyl)amino-1-pyridyl]-acetate (51c)**, was isolated (81%) as colorless crystals: mp. 105-8°C; IR (KBr) 3378, 1746, 1680, 1646, 1597, 1517, 1221; <sup>1</sup>H NMR (CDCl<sub>3</sub>)  $\delta$  8.34 (1H, d, *J* = 7.7), 8.25 (1H, s), 7.23 (10H, m), 6.11 (1H, d, *J* = 7.7), 4.77 (2H, s), 3.78 (3H, s), 2.88 (8H, m).

**Methyl [6-butyl-1,2-dihydro-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl]-acetate (51d)**, was isolated (88%) as colorless crystals: mp. 84-5°C; IR (KBr) 3345, 2958, 2930, 1756, 1693, 1650, 1602, 1510, 1227, 1180, 1137; <sup>1</sup>H NMR (CDCl<sub>3</sub>)  $\delta$  8.34 (1H, d, *J* = 7.7), 8.22 (1H, s), 7.26 (5H, m), 6.12 (1H, d, *J* = 7.7), 4.80 (2H, s), 3.79 (3H, s), 3.03 (2H, t), 2.68 (2H, t), 2.50 (2H, t), 1.46 (4H, m), 0.95 (3H, t).

**Methyl [1,2-dihydro-6-methyl-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl]-acetate (51e)**, was isolated (100%) as a pale yellow oil: IR (film) 3264, 1745, 1691, 1644, 1587, 1566, 1518, 1495, 1400, 1215, 1183, 1136; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 8.33 (1H, d, *J* = 7.6), 7.26 (5H, m), 6.13 (1H, d, *J* = 7.6), 4.83 (2H, s), 3.79 (3H, s), 3.03 (2H, m), 2.69 (2H, m), 2.28 (3H, s).

**Methyl [1,2-dihydro-2-oxo-6-phenyl-3-(3-phenylpropionyl)amino-1-pyridyl]-acetate (51f)**, was isolated (99%) as a pale yellow oil: IR (film) 3365, 3299, 1751, 1689, 1643, 1600, 1563, 1519, 1493, 1419, 1370, 1224; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 8.46 (1H, d, *J* = 7.7), 8.32 (1H, s), 7.32 (10H, m), 6.24 (2H, d, *J* = 7.7), 4.57 (2H, s), 3.73 (3H, s), 3.06 (2H, m), 2.72 (2H, m).

**Methyl [1,2-dihydro-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl]-acetate (51g)**, was isolated (81%) as an oil: IR (film) 3330, 1753, 1689, 1650, 1600, 1560, 1517, 1374, 1225, 1208; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 8.43 (1H, dd, *J* = 7.4, 1.7), 8.33 (1H, s), 7.28 (5H, m), 6.92 (1H, dd, *J* = 6.9, 1.7), 6.29 (1H, t), 4.67 (2H, s), 3.79 (3H, s), 3.04 (2H, m), 2.70 (2H, m). MS FAB (+) *M* + = 315 (*M* + 1).

**2(S) Methyl 2-methyl-[6-benzyl-1,2-dihydro-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl]-acetate (51h)**, was isolated (93%) as a colorless oil; [α]<sub>D</sub><sup>30</sup> -19° (c 1, CH<sub>2</sub>Cl<sub>2</sub>); IR (film) 3354, 3313, 3028, 2950, 1745, 1687, 1645, 1600, 1567, 1514, 1454, 1225; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 8.35 (1H, d, *J* = 7.5), 8.26 (1H, s), 7.27 (10H, m), 6.20 (1H, d, *J* = 7.5), 4.65 (1H, q, *J* = 6.8), 3.99 (2H, s), 3.71 (3H, s), 3.03 (2H, m), 2.68 (2H, m), 1.31 (3H, d, *J* = 6.8).

**Methyl [3-(N-acetyl-O-benzyl-L-tyrosine)amino-6-benzyl-1,2-dihydro-2-oxo-pyridyl]acetate (51i).** A stirred mixture of methyl [3-amino-6-benzyl-1,2-dihydro-2-oxo-1-pyridyl]acetate (100mg, 0.367mmol), Boc-Tyr(Bn)-OH (136mg, 0.367mmol), dimethylformamide (1ml), diisopropylethylamine (0.25ml, 1.468mmol) and 2-(1H-benzotriazol-1-yl)-1,1,3,3-tetramethyluronium hexafluorophosphate (118mg, 0.367mmol) was kept overnight at room temperature. The mixture was diluted with ethyl acetate, washed twice with 1M hydrochloric acid, twice with aqueous sodium bicarbonate, once with brine, then dried (MgSO<sub>4</sub>) and concentrated. The residue was purified by flash chromatography (10% ethyl acetate/dichloromethane) to afford a 162mg (70%) of a colorless oil. The oil (160mg, 0.255mmol) was dissolved in dichloromethane (1ml) and treated with trifluoroacetic acid (1ml) at 0°C. The resulting solution was allowed to reach room temperature during 40min then evaporated to dryness at 30°C. The residue was dissolved in dichloromethane then evaporated to dryness again. This procedure was repeated three times. The residue was dissolved in pyridine (0.5ml) and treated with acetic anhydride (0.03ml, 0.3mmol) at 0°C. The resulting mixture was allowed to reach room temperature and kept for 3.5h. It was diluted with ethyl acetate, washed twice with 1M hydrochloric acid, twice with aqueous sodium bicarbonate, dried (MgSO<sub>4</sub>) and concentrated to afford 128mg (86%) of a colorless oil: IR (film) 3290, 1751, 1649, 1602, 1568, 1513, 1455, 1438, 1375, 1224, 1179; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 8.78 (1H, s), 8.33 (1H, d, J = 7.6), 7.33 (8H, m), 7.11 (4H, m), 6.86 (2H, d, J = 8.5), 6.47 (1H, d, J = 7.6), 6.12 (1H, d, J = 7.6), 4.99 (2H, s), 4.85 (1H, m), 4.69 (2H, s), 3.87 (2H, s), 3.62 (3H, s), 3.08 (2H, m), 1.96 (3H, s).

Methyl [6-benzyl-1,2-dihydro-2-oxo-3-(2-phenylethanesulphonyl)amino-1-pyridyl]-acetate (51j). 2-Phenylethanesulphonyl chloride (Zhong et al., J. Am. Chem. Soc., 113, pp. 2259-63 (1991)) was added to a stirred mixture of methyl [3-amino-6-benzyl-2-oxo-1,2-dihydro-1-pyridyl]-acetate (49b) (1.0g, 3.67mmol), dichloromethane (15ml) and triethylamine (1.0ml, 7.34mmol). The mixture was kept overnight then poured into ethyl acetate. The resulting mixture was washed twice with aqueous sodium bicarbonate, three times with 1M hydrochloric acid, then brine. It was dried (MgSO<sub>4</sub>) and concentrated. The resulting pale brown solid was purified by flash chromatography (10% ethyl acetate/dichloromethane) to afford 1.25g (77%) of a pale yellow solid: m.p. 92-4°C; IR (KBr) 3181, 1737, 1646, 1595, 1565, 1454, 1241, 1220, 1150; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.53 (1H, d, J = 7.5), 7.29 (10H, m), 6.10 (1H, d, J = 7.5), 4.75 (2H, s), 3.89 (2H, s), 3.67 (3H, s), 3.34 (2H, m), 3.14 (2H, m).

Methyl [6-benzyl-1,2-dihydro-2-oxo-3-(4-phenylbutyryl)amino-1-pyridyl]-acetate (51l), was isolated (74%) as colorless crystals: mp. 93-95°C; IR (KBr) 3285, 1747, 1683, 1642, 1591, 1563, 1512, 1455, 1220, 1181; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 8.39 (1H, d, J = 7.6), 8.24 (1H, s), 7.2 (10H, m), 6.18 (1H, d, J = 7.6), 4.7 (2H, s), 3.90 (2H, s), 3.67 (3H, s), 2.69 (2H, t), 2.40 (2H, t), 2.04 (2H, m).



2(S) 2-[1,2-Dihydro-2-oxo-3-(3-phenylpropionyl)amino]-  
1-pyridyl]propionic acid (52a). 1M Sodium hydroxide  
(15ml, 15mmol) was added to a stirred solution of 2(S)  
methyl 2-[1,2-dihydro-2-oxo-3-(3-phenylpropionyl)amino-  
5 1-pyridyl]propionate (51a) (2.39g, 7.3mmol) in methanol  
(30ml) at 0°C. The mixture was kept at this  
temperature for 2h, acidified with 1M hydrochloric acid  
(15.1ml) and extracted with ethyl acetate. The  
extracts were washed with brine, dried (MgSO<sub>4</sub>) and  
10 concentrated to afford 1.98g (87%) of a colorless  
solid:  $[\alpha]_D^{20}$  -75° (1, CH<sub>2</sub>Cl<sub>2</sub>); IR (KBr) 3301, 1724,  
1693, 1637, 1563, 1523, 1453, 1233, 1216, 765; <sup>1</sup>H NMR  
(CDCl<sub>3</sub>) δ 8.47 (2H, m), 7.20 (5H, m), 7.03 (1H, d), 6.36  
(1H, t), 5.35 (1H, q), 3.01 (2H, m), 2.70 (2H, m), 1.69  
15 (3H, m).

The following compounds were prepared in a similar  
manner:

[6-Benzyl-1,2-dihydro-2-oxo-3-(3-phenylpropionyl)amino-  
1-pyridyl]acetic acid (52b), was isolated (100%) as a  
20 pale amber oil: IR (film) 3291, 1738, 1686, 1644,  
1591, 1554, 1519, 1496, 1454, 1403, 1215, 1182; <sup>1</sup>H NMR  
(CDCl<sub>3</sub>) δ 8.44 (1H, d, *J* = 7.8), 8.4 (1H, s), 7.21 (10H,  
m), 6.19 (1H, d, *J* = 7.8), 4.71 (2H, s), 3.90 (2H, s),  
2.99 (2H, m), 2.71 (2H, m).

[1,2-Dihydro-2-oxo-6-phenethyl-3-(3-phenylpropionyl)  
25 amino-1-pyridyl]acetic acid (52c), was isolated (94%)  
as a beige solid: mp. 214-6°C; IR (KBr) 3289, 1740,  
1680, 1640; <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 9.24 (1H, s), 8.14 (1H,  
d, *J* = 7.7), 7.22 (10H, m), 6.11 (1H, d, *J* = 7.8), 4.78  
30 (2H, s), 2.81 (8H, m).

[6-Butyl-1,2-dihydro-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl]acetic acid (52d), was isolated (99%) as a pale brown solid: mp. 132-4°C; IR (KBr) 3286, 1739, 1676, 1641, 1584, 1555, 1535, 1455, 1414, 1249, 1227, 1204; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 8.42 (1H, d, J = 7.8), 8.37 (1H, s), 7.24 (5H, m), 6.19 (1H, d, J = 7.8), 4.82 (2H, s), 3.55 (1H, s), 3.00 (2H, t), 2.67 (2H, t), 2.53 (2H, t), 1.41 (4H, m), 0.94 (3H, t).

[1,2-Dihydro-6-methyl-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl]acetic acid (52e), was isolated as a solid (100%): mp. 159-61°C; IR (KBr) 3335, 1731, 1686, 1642, 1536, 1516, 1430, 1420, 1401, 1222, 1195; <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 9.21 (1H, s), 8.13 (1H, d, J = 7.6), 7.20 (5H, m), 6.15 (1H, d, J = 7.6), 4.77 (2H, s), 2.87 (2H, m), 2.70 (2H, m), 2.25 (3H, s).

[1,2-Dihydro-2-oxo-6-phenyl-3-(3-phenylpropionyl)amino-1-pyridyl]acetic acid (52f), was isolated (100%) as a pale yellow foam: IR (KBr) 3271, 1747, 1683, 1634, 1580, 1536, 1490, 1406, 1392, 1365, 1235, 1219; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 8.52 (1H, d, J = 7.7), 7.31 (10H, m), 6.48 (2H, s), 6.30 (1H, d, J 7.7), 4.60 (2H, s), 3.03 (2H, m), 2.71 (2H, m).

[1,2-Dihydro-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl]acetic acid (52g), was isolated (94%) as a colorless solid: mp. 195-7°C; IR (KBr) 3324, 1724, 1693, 1644, 1569, 1555, 1512, 1427, 1370, 1240; <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 9.31 (1H, s), 8.23 (1H, d, J = 6.8), 7.36 (1H, dd, J = 6.8, 1.71), 7.25 (5H, m), 6.25 (1H, t), 4.66 (2H, s), 2.84 (4H, m).

2(R,S) 2-[6-Benzyl-1,2-dihydro-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl]-propionic acid (52h),

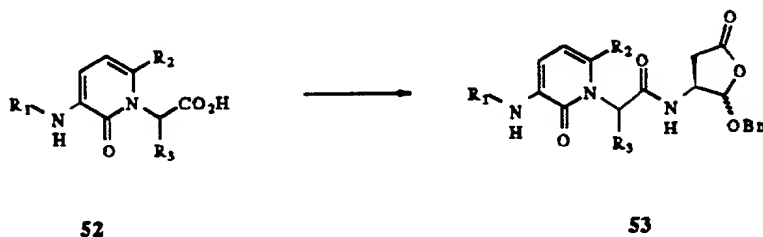
was prepared by hydrolysis of compound 51h in aqueous tetrahydrofuran during 5h at 40°C to afford (95%) as a yellow oil: IR (film) 3330, 1734, 1686, 1643, 1600, 1587, 1553, 1524, 1498, 1208; <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 9.29 (1H, s), 8.18 (1H, d, *J* = 7.6), 7.21 (10H, m), 6.22 (1H, d, *J* = 7.6), 4.82 (1H, q, *J* = 6.6), 4.08 (2H, m), 2.76 (4H, m), 1.05 (3H, d, *J* = 6.6).

**[3-(Acetyl-Tyr(Bn))amino-6-benzyl-1,2-dihydro-2-oxo-1-pyridyl]acetic acid (52i)**, was isolated (93%) as a foam: IR (KBr) 3302, 1731, 1646, 1603, 1562, 1512, 1454, 1428, 1379, 1231, 1178; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 9.48 (1H, s), 8.36 (1H, d, *J* = 7.6), 7.30 (8H, m), 7.10 (2H, m), 6.85 (2H, d, *J* = 8.3), 6.91 (2H, d, *J* = 8.3), 6.71 (1H, d, *J* = 7.6), 4.95 (1H, m), 4.90 (2H, s), 4.68 (2H, s), 3.92 (2H, s), 3.17-2.83 (2H, m), 1.92 (3H, s).

**[6-Benzyl-1,2-dihydro-2-oxo-3-(2-phenylethanesulphonyl)amino-1-pyridyl]acetic acid (52j)**, was isolated (100%) as a colorless solid: mp. 165-7°C; IR (KBr) 3174, 1760, 1646, 1593, 1567, 1497, 1453, 1424, 1326, 1225, 1140, 1127; <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 13.09 (1H, s), 9.08 (1H, s), 7.30 (11H, m), 6.02 (1H, d), 4.68 (2H, s), 4.99 (2H, s), 3.29 (2H, m), 3.03 (2H, m).

**[6-Benzyl-1,2-dihydro-2-oxo-3-(2-phenylethoxy)carbonylamino-1-pyridyl]acetic acid (52k)**, was prepared (70%) by hydrolysis of compound 49i during 1h at 60°C: IR (CH<sub>2</sub>Cl<sub>2</sub>) 1797, 1689, 1649, 1601, 1512, 734; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 8.39 (1H, s), 8.03 (1H, d), 7.81 (1H, s), 7.33-7.07 (10H, m), 6.13 (1H, d, *J* = 7.8), 4.72 (2H, s), 4.33 (2H, t, *J* = 7.0), 3.86 (2H, s), 2.93 (2H, t, *J* = 7.0).

[6-Benzyl-1,2-dihydro-2-oxo-3-(4-phenylbutyryl)amino-1-pyridyl]acetic acid (521), was isolated (100%) as a white foam: m.p. 159-161°C; IR (KBr) 3373-3310, 1787, 1726, 1691, 1649, 1599, 1567, 1517, 1367, 1215; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 8.43 (1H, d, *J* = 7.7), 8.25 (1H, s), 7.37-7.09 (10H, m), 6.21 (1H, d, *J* = 7.7), 4.73 (2H, s), 4.15 (3H, s), 3.91 (2H, s), 2.67 (2H, t), 2.39 (2H, t), 2.02 (2H, m).



2(*S*), *N*-3(*S*) 2-[1,2-Dihydro-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl]-*N*-(2-benzyloxy-5-oxotetrahydrofuran-3-yl)propionamide (53a). Tri-*n*-butyltin hydride (1.7ml, 6.3mmol) was added dropwise to a stirred mixture of 2(*S*)-2-[1,2-dihydro-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl]propionic acid (52a) (1.1g, 3.49mmol), 3(*S*), 2(*R,S*) 3-allyloxycarbonylamino-2-benzyloxy-5-oxotetrahydrofuran (1.02g, 3.49mmol; Chapman, Biorg. Med. Chem. Lett., 2, pp. 613-18 (1992)), bis(triphenylphosphine)palladium (II) chloride (55mg), dichloromethane (35ml) and dimethylformamide (1ml). The resulting mixture was stirred for 5 min. then 1-hydroxybenzotriazole (946mg, 7mmol) was added. The mixture was cooled to 0°C before the addition of 1-(3-dimethylaminopropyl)-2-ethylcarbodiimide hydrochloride (740mg, 3.84mmol). The mixture was kept overnight at room temperature then poured into ethyl acetate. The mixture was washed twice with 1M hydrochloric acid, twice with aqueous sodium bicarbonate, then brine. The mixture was dried (MgSO<sub>4</sub>)



and concentrated. The residue was triturated with pentane. The remaining solid was purified by flash chromatography (40-60% ethyl acetate/hexane) to afford 1.28g (73%) of colorless solid: IR (KBr) 1796, 1692, 1647, 1595, 1557, 1512, 1119; <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 9.28, 9.26 (1H, 2 x s), 8.77, 8.69 (1H, 2 x d), 8.24, 8.20 (1H, 2 x dd), 7.20 (11H, m), 6.31, 6.26 (1H, 2 x t), 5.65 (0.5H, d), 5.46 (0.5H, d), 5.41, 5.28 (1H, 2 x q), 4.7 (2.5H, m), 4.24 (0.5H, t), 3.24 (2H, m), 2.80 (4H, m), 1.51, 1.46 (3H, 2 x d).

The following compounds were prepared in a similar manner:

**N(3(S)) 2[6-Benzyl-1,2-dihydro-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl]-N-(2-benzyloxy-5-oxotetrahydrofuran-3-yl)acetamide (53b)**, was obtained (86%) as a foam: IR (KBr) 3345, 3297, 1807, 1791, 1688, 1679, 1650, 1602, 1554, 1525, 1497, 1453, 1372, 1257, 1119; <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 9.25 (0.5H, s), 9.23 (0.5H, s), 8.75 (0.5H, d, *J* = 6.5), 8.67 (0.5H, d, *J* = 7.4), 8.18 (1H, 2d), 7.21 (15H, m), 6.07 (1H, 2d), 5.65 (0.5H, d, *J* = 5.0), 5.38 (0.5H, s), 4.83-4.45 (4.5H, m), 4.19 (0.5H, m), 3.94, 3.83 (2H, m), 3.10-2.31 (6H, m).

**N(3(S)) 2[1,2-Dihydro-2-oxo-6-phenethyl-3-(3-phenylpropionyl)amino-1-pyridyl]-N-(2-benzyloxy-5-oxotetrahydrofuran-4-yl)acetamide (53c)**, was obtained (74%) as a mixture of anomers: <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 9.71 (1H, d), 9.41 (0.5H, d), 9.25 (0.5H, d), 8.64 (1H, d, *J* = 7.7), 7.75 (15H, m), 6.61 (1H, 2d), 6.11 (0.5H, d), 5.93 (0.5H, s), 5.17 (5H, m), 4.77 (0.5H, m), 3.68-2.94 (2H, m), 3.32 (8H, m).

- 5 **N(3(S)) 2[6-Butyl-1,2-dihydro-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl]-N-(2-benzyloxy-5-oxotetrahydrofuran-3-yl)acetamide (53d)**, was obtained (74%) as a mixture of anomers: IR (KBr) 3300, 1791, 1689, 1645, 1597, 1566, 1546, 1514, 1454, 1417, 1378;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  8.38 (1H, d,  $J = 7.7$ ), 8.13 (1H, s), 7.30 (10H, m), 6.18 (1H, t), 5.47 (0.5H, d,  $J = 5.2$ ), 5.43 (0.5H, s), 4.75 (4.5H, m), 4.38 (0.5H, m), 3.08-2.35 (8H, m), 1.43 (4H, m), 0.95 (3H, t).
- 10 **N(3(S)) 2[1,2-Dihydro-6-methyl-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl]-N-(2-benzyloxy-5-oxotetrahydrofuran-3-yl)acetamide (53e)**, was obtained (67%) as a mixture of anomers: IR (KBr) 3282, 1774, 1667, 1651, 1596, 1561, 1556, 1498, 1265, 1254, 1236, 1199, 1143;  $^1\text{H}$  NMR ( $d_6$ -DMSO)  $\delta$  9.17 and 9.15 (1H, 2 x s), 8.89 (0.5H, d,  $J = 6.5$ ), 8.73 (0.5H, d,  $J = 7.4$ ), 7.25 (10H, m), 6.13 (1H, t), 5.64 (0.5H, d,  $J = 5.0$ ), 5.45 (0.5H, s), 4.89-4.61 (4.5H, m), 4.26 (0.5H, m), 3.17-2.36 (6H, m), 2.23 and 2.15 (3H, 2s).
- 20 **N(3(S)) 2-[1,2-Dihydro-2-oxo-6-phenyl-3(3-phenylpropionyl)amino-1-pyridyl]-N-(2-benzyloxy-5-oxotetrahydrofuran-3-yl)acetamide (53f)**, was obtained (73%) as a mixture of anomers: IR (KBr) 3296, 1792, 1691, 1643, 1595, 1561, 1514, 1489, 1453, 1420, 1373, 1230, 1118;  $^1\text{H}$  NMR ( $d_6$ -DMSO)  $\delta$  9.40, 9.36 (1H, 2s), 8.70 (0.5H, d,  $J = 7.6$ ), 8.52 (0.5H, d,  $J = 7.5$ ), 8.29 (1H, dd), 7.25 (15H, m), 6.20 (1H, d,  $J = 7.6$ ), 5.61 (0.5H, d,  $J = 5.0$ ), 5.28 (0.5H, s), 4.78-4.20 (5H, m), 3.12-2.24 (6H, m).
- 30 **N(3(S)) 2-[1,2-Dihydro-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl]-N-(2-benzyloxy-5-oxotetrahydrofuran-3-yl)acetamide (53g)**, was obtained (70%) as a mixture of

anomers: IR (KBr) 3336, 3290, 1791, 1691, 1646, 1595, 1582, 1556, 1518, 1454, 1376, 1351, 1150, 1122; <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 9.26 (1H, 2s), 8.86 (0.5H, d, *J* = 6.4), 8.67 (0.5H, d, *J* = 7.5), 8.23 (1H, m), 7.40-7.13 (11H, m), 6.24 (1H, 2t, *J* = 7.2), 5.61 (0.5H, d, *J* = 5.0), 5.44 (0.5H, s), 4.83-4.59 (2.5H, m), 4.25 (0.5H, m), 3.15-2.34 (2H, m), 2.91-2.70 (4H, m). Anal. Calc. for C<sub>27</sub>H<sub>27</sub>N<sub>3</sub>O<sub>6</sub> · H<sub>2</sub>O: C, 63.90; H, 5.76; N, 8.28. Found: C 63.70; H, 5.68; N, 8.22. MS FAB M<sup>+</sup> = 490 (M + 1).

2(R, S), N(3(S)) 2-[6-Benzyl-1,2-dihydro-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl]-N(2-benzyloxy-5-oxotetrahydrofuran-3-yl)propionamide (53h), was obtained (89%) as a mixture of diastereomers. Data is given for a single diastereomer: IR (film) 3356, 1788, 1677, 1645, 1602, 1517, 1455, 1377, 1203, 1167, 1120; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 8.34 (1H, d, *J* = 7.6), 8.19 (1H, s), 7.38-7.13 (10H, m), 6.26 (1H, d, *J* = 7.6), 5.58 (1H, t), 5.31, 5.24 (1H, 2 x s), 4.62 (2H, 2q), 4.60 (1H, m), 4.27 (1H, m), 2.98, 2.68 (4H, 2m), 3.0-2.0 (2H, m), 1.42 (3H, d).

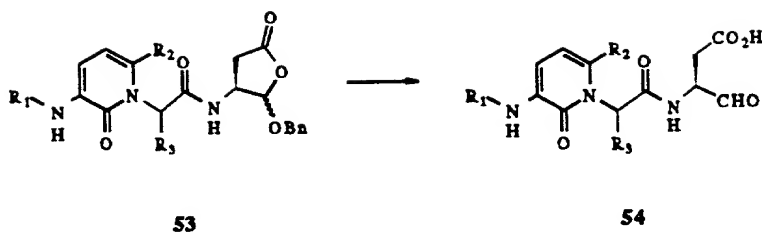
N(3(S)) 2-[6-Benzyl-1,2-dihydro-2-oxo-3-(N-acetyl-O-benzyltyrosinyl)amino-1-pyridyl]-N-(2-benzyloxy-5-oxotetrahydrofuran-3-yl)acetamide (53i), was obtained (76%) as a mixture of anomers: IR (KBr) 1794, 1698, 1651, 1612, 1514, 1454, 1374, 1247, 1177, 1126; <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 9.34, 9.31 (2 x 0.5H, 2s), 8.71 (1H, 2d), 8.38 (1H, m), 8.17 (1H, d), 7.48-6.88 (19H, m), 6.08 (1H, 2d), 5.65 (0.5H, d, *J* = 5.0), 5.40 (0.5H, s), 5.04 (2H, s), 4.68 (5.5H, m), 4.15 (0.5H, m), 3.95, 3.84 (2H, s + abq), 3.20-2.40 (4H, m), 1.78 (3H, s).

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**N(3(S)) 2-[6-Benzyl-1,2-dihydro-2-oxo-3-(2-phenylethanesulphonyl)amino-1-pyridyl]-N-(2-benzyloxy-5-oxotetrahydrofuran-3-yl)acetamide (53j)**, was obtained (78%) as a mixture of anomers: IR (KBr) 3344, 1792, 1691, 1647, 1599, 1566, 1454, 1365, 1150, 1121, 973; <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 9.02, 8.99 (1H, 2s), 8.80 (0.5H, d, *J* = 6.4), 8.70 (0.5H, d, *J* = 7.4), 7.26 (15H, m), 6.00 (1H, dd), 5.63 (0.5H, d, *J* = 5.0), 5.39 (0.5H, s), 4.68 (4.5H, m), 4.18 (0.5H, m), 3.90 (2H, m), 3.30-2.30 (6H, m).

**N(3(S)) 2-[6-Benzyl-1,2-dihydro-2-oxo-3-(2-phenylethoxy)carbonylamino-1-pyridyl]-N-(2-benzyloxy-5-oxotetrahydrofuran-3-yl)acetamide (53k)**, was obtained (78%) as a mixture of anomers: IR (KBr) 3386, 1794, 1726, 1650, 1603, 1518, 1366, 1214, 699; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 8.03 (1H, bd), 7.63, 7.61 (1H, 2 x s), 7.34-7.04 (15H, m), 6.21, 6.18 (1H, 2d), 5.44 (0.5H, d, *J* = 5.4), 5.37 (0.5H, s), 4.85, 4.83 (1H, 2d, *J* = 11.6, 11.5), 4.61-4.48, 4.32 (4H, 2m), 4.4 (2H, t), 4.08, 4.03 (2H, 2bs), 3.07-2.78 (3H, m), 2.47-2.30 (1H, m).

**N(3(S)) 2-[6-Benzyl-1,2-dihydro-2-oxo-3-(4-phenylbutyryl)amino-1-pyridyl]-N-(2-benzyloxy-5-oxotetrahydrofuran-3-yl)acetamide (53l)**, was obtained (86%) as a colorless oil: IR (CH<sub>2</sub>Cl<sub>2</sub>) 1797, 1689, 1649, 1601, 1512, 734; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 8.42, 8.40 (1H, 2d, *J* = 7.6), 7.35-7.07 (15H, m), 6.21, 6.19 (1H, 2d, *J* = 7.6), 5.44 (0.5H, d), 5.37 (0.5H, s), 4.84, 4.81 (1H, 2d, *J* = 11.7, 11.4), 4.73-4.48, 4.34 (4H, 2m), 4.05 (2H, m), 3.05-2.63, 2.46-2.30 (6H, 2m), 2.01 (2H, m).



	$R_1$	$R_2$	$R_3$
5	(a) $\text{Ph}(\text{CH}_2)_2\text{CO}$	H	(S) Me
	(b) $\text{Ph}(\text{CH}_2)_2\text{CO}$	$\text{CH}_2\text{Ph}$	H
	(c) $\text{Ph}(\text{CH}_2)_2\text{CO}$	$(\text{CH}_2)_2\text{Ph}$	H
	(d) $\text{Ph}(\text{CH}_2)_2\text{CO}$	nBu	H
	(e) $\text{Ph}(\text{CH}_2)_2\text{CO}$	Me	H
	(f) $\text{Ph}(\text{CH}_2)_2\text{CO}$	Ph	H
	(g) $\text{Ph}(\text{CH}_2)_2\text{CO}$	H	H
	(h) $\text{Ph}(\text{CH}_2)_2\text{CO}$	$\text{CH}_2\text{Ph}$	(R, S) -Me
10	(i) AcTyr	$\text{CH}_2\text{Ph}$	H
	(j) $\text{Ph}(\text{CH}_2)_2\text{SO}_2$	$\text{CH}_2\text{Ph}$	H
	(k) $\text{Ph}(\text{CH}_2)_2\text{OCO}$	$\text{CH}_2\text{Ph}$	H
	(l) $\text{Ph}(\text{CH}_2)_3\text{CO}$	$\text{CH}_2\text{Ph}$	H

15 **3(S), N(2(S)) 3-(2-(1,2-Dihydro-2-oxo-3-(3-phenylpropionylamino-1-pyridyl)-propionylamino)-4-oxo-butanoic acid (54a; F).** A mixture of 2(S), N(3(S)) 2-[1,2-dihydro-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl]-N(2-benzyloxy-5-oxotetrahydro-furan-3-yl)propionamide **53a** (1.28g, 2.5mmol), methanol (140ml)

20 ethyl acetate (60ml) and 10% palladium on carbon (1.4g) was stirred under an atmosphere of hydrogen. After 2.5h more catalyst (300mg) was added and hydrogenation continued for 1h. The mixture was filtered through Celite™ and then refiltered through 0.2μM nylon filter

and concentrated. The residual oil triturated with a mixture of methanol and ether to afford 916mg (87%) of colorless crystals: mp. 198-200°C;  $[\alpha]_D^{28}$  -120° (0.1, CH<sub>3</sub>OH); IR (KBr) 3330, 1794, 1688, 1644, 1583, 1556, 1515, 1427; <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 8.28 (1H, d), 7.35 (1H, d), 7.20 (5H, m), 6.36 (1H, t), 5.49 (1H, q), 4.59 (1H, t), 4.25 (1H, m), 2.98, 2.74 (2 x 2H, 2 x m), 2.59 (2H, m), 1.57 (3H, d). Anal. Calcd for C<sub>21</sub>H<sub>23</sub>N<sub>3</sub>O<sub>6</sub> 0.75 H<sub>2</sub>O: C, 59.08; H, 5.78; N, 9.84. Found: C 59.24; H, 5.96; N, 9.84. FAB M<sup>+</sup> = 414 (M + 1), 297, 165, 91.

The following compounds were prepared in a similar manner:

**3(S) 3-(6-Benzyl-1,2-dihydro-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl)acetylamino-4-oxobutanoic acid, (54b; M)**, was isolated (59%) as colorless crystals: mp. 115°C (decomp); IR (KBr) 3440, 3297, 1718, 1646, 1598, 1565, 1526, 1496, 1260; <sup>1</sup>H NMR (CD<sub>3</sub>OD) 8.25 (1H, d, J=7.7), 7.25 (10H, m), 6.15 (1H, 2d, each J=7.7), 4.73 (2H, 2q), 4.59 (1H, m), 4.30 (1H, m), 3.95 (2H, s), 2.98 (2H, m), 2.75 (2H, m), 2.8-2.42 (2H, m). Anal. Calcd for C<sub>27</sub>H<sub>27</sub>N<sub>3</sub>O<sub>6</sub> 0.7 H<sub>2</sub>O: C, 64.58; H, 5.70; N, 8.37. Found: C, 64.51; H, 5.63; N, 8.38. MS FAB+ M<sup>+</sup> = 490 (M + 1).

**3(S) 3-(1,2-Dihydro-2-oxo-6-phenethyl-3(3-phenylpropionyl)amino-1-pyridyl)acetylamino-4-oxobutanoic acid (54c)**, was isolated (46%) as a white solid: IR (KBr) 3375, 1694, 1643, 1586, 1561, 1515, 1377, 1254, 1188, 1070; <sup>1</sup>H NMR (CD<sub>3</sub>OD) 8.18 (1H, d, J=7.8), 7.22 (10H, m), 6.15 (1H, d, J=7.8), 4.75 (2H, s), 4.58 (1H, m), 4.30 (1H, m), 3.01-2.28 (10H, m); MS FAB+ M<sup>+</sup> = 504 (M + 1).

3(S) 3-(6-Butyl-1,2-dihydro-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl)acetyl-amino-4-oxobutanoic acid (54d), was isolated (90%) as colorless crystals: m.p. 120-5°C; IR (KBr) 3315, 1784, 1679, 1644, 1589, 1561, 1556, 1520, 1415, 1379, 1186; <sup>1</sup>H NMR (CD<sub>3</sub>OD) 8.22 (1H, d, J=7.8), 7.24 (5H, m), 6.22 (1H, d, J=7.8), 4.80 (2H, m), 4.60 (1H, s), 4.28 (1H, m), 2.98 (2H, m), 2.72 (2H, m), 2.58 (4H, m), 1.48 (4H, m), 0.97 (3H, t, J=7.1). Anal. Calcd for C<sub>24</sub>H<sub>29</sub>N<sub>3</sub>O<sub>6</sub> 0.5 H<sub>2</sub>O. C, 62.06; H, 6.51; N, 9.05. Found: C, 62.08; H, 6.43; N, 9.01. MS FAB+ M+ = 456 (M + 1).

3(S) 3-(1,2-Dihydro-6-methyl-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl)acetyl-amino-4-oxobutanoic acid (54e), was isolated (85%) as a colorless solid: mp. 129-138°C; IR (KBr) 327, 3294, 1710, 1695, 1682, 1554, 1525, 1379, 1272, 1240; <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 8.19 (1H, d, J=7.6), 7.19 (5H, m), 6.21 (1H, d, J=7.6), 4.80 (2H, m), 4.59 (1H, m), 4.30 (1H, m), 2.98 (2H, m), 2.72 (2H, m), 2.80-2.40 (2H, m), 2.30 (3H, s). Anal. Calcd for C<sub>21</sub>H<sub>22</sub>N<sub>3</sub>O<sub>6</sub> · H<sub>2</sub>O: C, 58.46; H, 5.84; N, 9.74. Found C: 58.82; H, 60.5; N, 9.42.

3(S) 3-(1,2-Dihydro-2-oxo-6-phenyl-3-(3-phenylpropionyl)amino-1-pyridyl)acetyl-amino-4-oxobutanoic acid (54f), 73% as an off-white solid: m.p. 140°C (decomp). [α]<sub>D</sub><sup>24</sup> = -8.5° (c 0.1, MeOH). IR (KBr) 3302, 1796, 1726, 1679, 1643, 1590, 1560, 1516, 1490, 1449, 1420, 1398, 1376, 1231; <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 8.36 (1H, d), 7.49-7.14 (10H, m), 6.27 (1H, dd), 4.54 (3H, m), 4.30 (1H, m), 3.0, 2.73 (2 x 2H, 2 x m), 2.7-2.29 (2H, m).

3(S) 3-(1,2-Dihydro-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl)acetyl-amino-4-oxobutanoic acid (54g; G), was isolated (73%) as a foam: mp. 140-5°C (decomp); IR

(KBr) 3352, 3314, 1719, 1700, 1668, 1649, 1600, 1559, 1514, 1379, 1261;  $^1\text{H}$  NMR ( $\text{CD}_3\text{OD}$ )  $\delta$  8.32 (1H, d,  $J=7.5$ ), 7.19 (6H, m), 6.34 (1H, t), 5.1-4.6 (3H, m), 4.32 (1H, m), 2.7 (6H, m). Anal. Calcd for  $\text{C}_{20}\text{H}_{21}\text{N}_3\text{O}_6 \cdot 0.6\text{H}_2\text{O}$ : C, 58.50, H, 5.45, N, 10.24. Found: C, 58.43, H, 5.35, N, 9.85. MS FAB+  $M + = 400$  ( $M + 1$ ).

3(*S*), N(2(*R,S*)) 3-(2-(6-Benzyl-1,2-dihydro-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl)propionylamino)-4-oxobutanoic acid (54h), was obtained (69%) as a colorless foam: m.p.  $120^\circ\text{C}$ ;  $[\alpha]_D^{20} -16.0^\circ$  ( $c$ , 0.11,  $\text{CH}_2\text{Cl}_2$ ). IR (KBr) 3315, 1783, 1727, 1666, 1644, 1599, 1564, 1517, 1454, 1379;  $^1\text{H}$  NMR ( $\text{CD}_3\text{OD}$ )  $\delta$  8.23 (1H, m), 7.27 (10H, m), 6.28 (1H, m), 4.84 (1H, m), 4.53 (1H, m), 4.22 (1H, m), 4.10 (2H, m), 2.96 (2H, m), 2.72 (2H, m), 2.39 (2H, m), 1.21 (3H, m). Anal. Calcd for  $\text{C}_{28}\text{H}_{29}\text{N}_3\text{O}_6 \cdot 1.25\text{H}_2\text{O}$ : C, 63.93, H, 6.03, N, 7.99. Found: C, 63.98, H, 5.85, N, 7.86. MS FAB (+)  $M + = 504$  ( $M + 1$ ).

3(*S*) 3-(3-(2-Acetyl-L-tyrosinyl)amino-6-benzyl-1,2-dihydro-2-oxo-1-pyridyl)acetylamino-4-oxobutanoic acid (54i), was isolated (79%) as colorless crystals: mp.  $193-6^\circ\text{C}$  (decomp.); IR (KBr) 3284, 1644, 1599, 1565, 1519, 1455, 1429, 1407, 1375, 1267, 1251;  $^1\text{H}$  NMR ( $d_6$ -DMSO/ $\text{CDCl}_3$ )  $\delta$  8.16 (1H, d,  $J=7.7$ ), 7.26 (5H, m), 7.03 (2H, d,  $J=8.4$ ), 6.61 (2H, d,  $J=8.4$ ), 6.03 (1H, d,  $J=7.7$ ), 4.58 (3H, m), 4.44 (1H, m), 4.13 (1H, m), 3.84 (2H, s), 3.07-2.30 (4H, m). Anal. Calcd for  $\text{C}_{29}\text{H}_{30}\text{N}_4\text{O}_8 \cdot 2\text{H}_2\text{O}$ : C, 58.19; H, 5.72; N, 9.36. Found: C, 58.11; H, 5.63; N, 9.29. MS FAB+  $M + = 563$  ( $M + 1$ ).

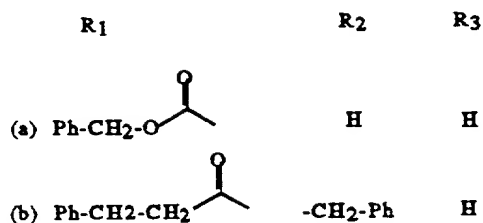
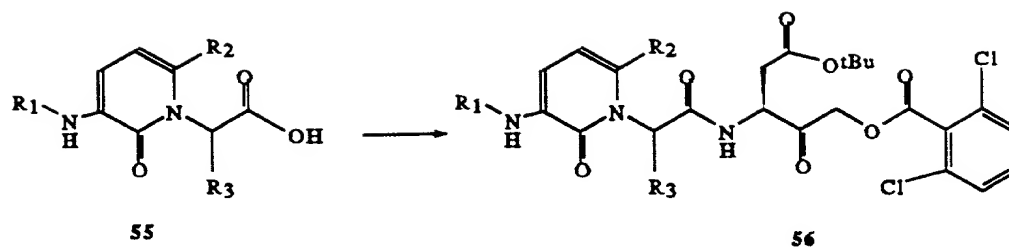
3(*S*) 3-(6-Benzyl-1,2-dihydro-2-oxo-3-(2-phenylethane-sulphonyl)amino-1-pyridyl)acetylamino-4-oxobutanoic acid (54j), was isolated (85%) as a colorless solid:



mp. 102-5°C;  $[\alpha]_D^{23}$  -9.9° (c 0.1, MeOH); IR (KBr) 3452, 3328, 3155, 1719, 1679, 1645, 1594, 1567, 1453, 1425, 1357, 1307, 1225, 1148, 1132;  $^1\text{H}$  NMR ( $\text{CD}_3\text{OD}$ )  $\delta$  7.52 (1H, d,  $J=7.6$ ), 7.33 (10H, m), 6.12 (1H, d,  $J=7.6$ ), 4.73 (2H, m), 4.58 (1H, d,  $J=3.7$ ), 4.34 (1H, m), 3.97 (2H, s), 3.29 (2H, m), 3.08 (2H, m), 2.75-2.37 (2H, m).  
Anal. Calcd for  $\text{C}_{26}\text{H}_{27}\text{N}_3\text{O}_7\text{S} \cdot 1.7\text{H}_2\text{O}$ : C, 56.14; H, 5.51; N, 7.55. Found: C, 56.20; H, 5.49; N, 7.29. MS FAB+  $\text{M}^+ = 526$  ( $\text{M} + 1$ ).

3(S) 3-(6-Benzyl-1,2-dihydro-2-oxo-3-(2-phenylethoxy)carbonylamino-1-pyridyl)acetylamino-4-oxobutanoic acid (54k), was isolated (54%) as an off-white solid: mp. 84-86°C; IR (KBr) 3373-3310, 1787, 1726, 1691, 1649, 1599, 1567, 1517, 1367, 1215;  $^1\text{H}$  NMR ( $\text{CD}_3\text{OD}$ )  $\delta$  7.93 (1H, bd,  $J=7.4$ ), 7.37-7.18 (10H, m), 6.15 (1H, d,  $J=7.4$ ), 4.77 (1H, d,  $J=3.7$ ), 4.67 and 4.58 (2H, 2m), 4.35 (2H, t,  $J=6.9$ ), 4.35 (1H, m), 3.94 (2H, s), 2.98 (2H, t,  $J=6.9$ ), 2.76-2.39 (2H, m).

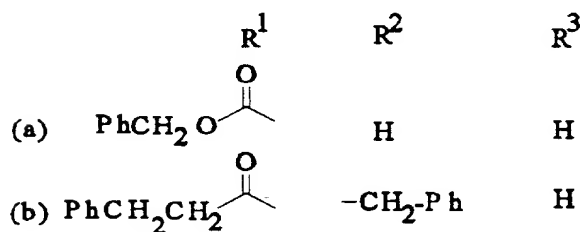
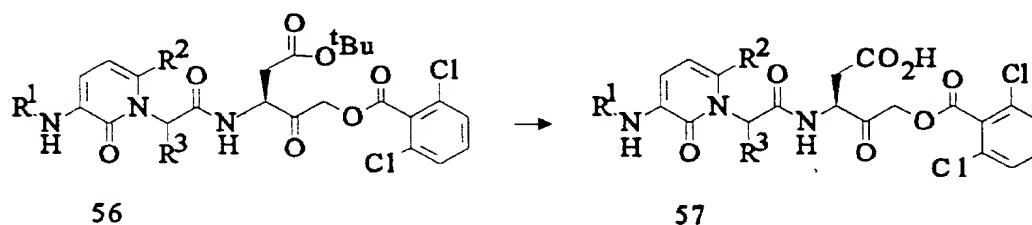
3(S) 3-(6-Benzyl-1,2-dihydro-2-oxo-3-(4-phenylbutyryl)carbonylamino-1-pyridyl)acetylamino-4-oxobutanoic acid (54l), was isolated (50%) as a white solid: mp. 89-93°C; IR (KBr) 3369-3302, 1678, 1645, 1594, 1565, 1517, 1379, 1258;  $^1\text{H}$  NMR ( $\text{d}_4$ -methanol)  $\delta$  8.25 (1H, d,  $J=7.6$ ), 7.37-7.18 (10H, m), 6.15 (1H, d,  $J=7.4$ ), 4.74 (2H, m), 4.60 (1H, m), 4.30 (1H, m), 3.97 (2H, s), 2.76-2.37 (2H, m), 2.67 (2H, t), 2.45 (2H, t), 1.98 (2H, m). Anal. Calcd for  $\text{C}_{28}\text{H}_{29}\text{N}_3\text{O}_6 \cdot 1.5\text{H}_2\text{O}$ : C, 63.39; H, 6.08; N, 7.92. Found C: 63.69; H, 5.74; N, 7.83.



t-Butyl N-2-(3-benzyloxycarbonylamino-1,2-dihydro-2-oxo-1-pyridyl)acetyl-3-amino-5-(2,6-dichlorobenzoyloxy)-4-oxo-pentanoate (56a). The acetic acid (55a) (WO 93 21213) in THF (2ml) was stirred at room temperature and treated with 1-hydroxybenzotriazole (60mg, 0.448mmol) and dimethylaminopropyl-3-ethylcarbodiimide hydrochloride (47mg, 0.246mmol). After 5 mins water (2 drops) was added and stirring continued for 20 minutes. Bis(triphenylphosphine) palladium II chloride (6mg) was added followed by a solution of t-butyl 3-(allyloxycarbonylamino)-4-oxo-5-(2,6-dichlorobenzoyl-oxy)pentanoate (WO 93 16710) (103mg, 0.224mmol) in THF (1ml). Tributyltin hydride (0.09ml, 0.336mmol) was added dropwise over 1 hour at room temperature. The mixture was stirred for a further 3 hours and poured onto ethyl acetate, washed with 1M HCl, aqueous NaHCO<sub>3</sub>, brine, dried over MgSO<sub>4</sub>, and concentrated in vacuo. The residue was triturated with pentane and the supernatant discarded. The remaining solid was purified by flash chromatography (50% ethyl acetate/hexane) to afford the title compound 92mg (63%)

as a colorless oil:  $[\alpha]_D^{26} -29.6^\circ$  (c 1.1,  $\text{CH}_2\text{Cl}_2$ ); IR (film) 3377, 3365, 3332, 3312, 1733, 1691, 1650, 1599, 1515, 1366, 1261, 1153, 1068, 747;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  8.09 (1H, d,  $J = 6.8$ ), 7.84 (1H, s), 7.58 (1H, d,  $J = 8.3$ ), 7.33 (8H, m), 7.02 (1H, dd,  $J = 6.9, 1.7$ ), 6.33 (1H, t,  $J = 7.2$ ), 5.20 (2H, s), 5.12 (2H, m), 4.89 (1H, dt), 4.65 (2H, m), 2.80 (2H, m), 1.38 (9H, s).

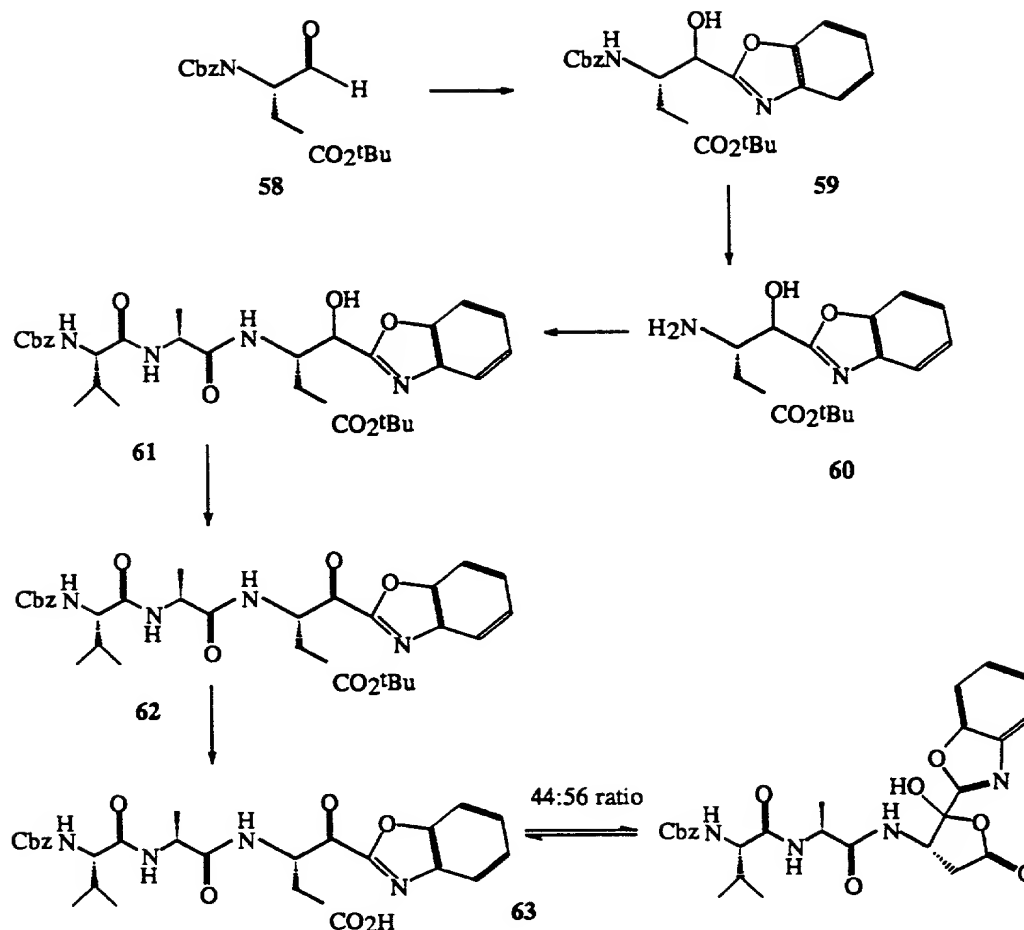
**t-Butyl N-2-(6-benzyl-1,2-dihydro-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl)acetyl-3-amino-5-(2,6-dichlorobenzyloxy)-4-oxo-pentanoate (56b)**, was prepared by the method described for (56a) which afforded the title compound (66%) as a colorless oil: IR (film) 3364, 3313, 1738, 1688, 1648, 1600, 1566, 1514, 1433, 1369, 1254, 1152;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  8.40 (1H, d,  $J = 7.6$ ), 8.30 (1H, s), 7.28 (13H, m), 6.20 (1H, d,  $J = 7.6$ ), 5.12 (2H, q), 4.86 (1H, m), 4.65 (2H, q), 4.06 (2H, s), 3.07-2.61 (6H, m), 1.39 (9H, s).



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**N-2(3-Benzylloxycarbonylamino-1,2-dihydro-2-oxo-1-pyridyl)acetyl-3-amino-5-(2,6-dichlorobenzoyloxy)-4-oxo-pentanoic acid (57a; Q).** The ester (56a) (210mg, 0.356mmol) in dichloromethane (0.5ml) was cooled to 0°C and treated with trifluoroacetic acid (0.5ml), stirred and warmed to 20°C over 30 minutes. The solution was evaporated to dryness under reduced pressure, redissolved in dichloromethane and concentrated (x3). The residue was triturated with ethyl acetate and diluted with ether to afford the title compound 162mg (85%) as a colorless solid: m.p. 165-8°C (decomposition);  $[\alpha]_D^{23}$  -38.8° (c 0.1, CH<sub>3</sub>OH); IR (KBr) 3332, 3275, 1723, 1658, 1649, 1597, 1581, 1562, 1526, 1432, 1385, 1258, 1218, 1206; <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 8.96 (1H, d, J = 7.3), 8.34 (1H, s), 7.85 (1H, dd, J = 7.3), 7.58 (3H, m), 7.35 (5H, m), 6.29 (1H, t, J = 7.3), 5.26 (2H, m), 5.15 (2H, s), 4.69 (3H, m), 2.75 (2H, m). Anal. Calcd. C<sub>27</sub>H<sub>23</sub>N<sub>3</sub>O<sub>9</sub>Cl<sub>2</sub>: C, 53.66; H, 3.84; N, 6.95. Found: C, 53.36; H, 3.90; N, 6.81. M.S. (+ FAB); 604 (M<sup>+</sup> + 1), 285, 241, 195, 173, 149, 91.

**N-2-(6-Benzyl-1,2-dihydro-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl)acetyl-3-amino-5-(2,6-dichlorobenzoyloxy)-4-oxo-pentanoic acid (57b; P),** was prepared by the method described for 57a which afforded the title compound (78%) as colorless crystals: m.p. 116-120°C (decomposition);  $[\alpha]_D^{26}$  -41.1° (c 0.1, CH<sub>3</sub>OH); IR (KBr) 3299, 1739, 1715, 1689, 1666, 1645, 1598, 1563, 1518, 1432, 1209, 1151; <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 9.24 (1H, s), 8.88 (1H, d, J = 7.6), 8.18 (1H, d, J = 7.7), 7.60 (3H, m), 7.26 (10H, m), 6.06 (1H, d, J = 7.7), 5.23 (2H, ABq), 4.69 (3H, m), 3.93 (2H, s), 2.78 (6H, m). Anal. Calcd. for C<sub>35</sub>H<sub>31</sub>N<sub>3</sub>O<sub>8</sub>Cl<sub>2</sub>. H<sub>2</sub>O: C, 59.16; H, 4.68; N, 5.91. Found: C, 59.38; H, 4.53; N, 5.84. M.S. (+ FAB); 694, (Cl=35, 37), (M<sup>+</sup> + 1); 692 (Cl=35, 35), (M<sup>+</sup> + 1).



(3*S*, 4*R*, *S*) *t*-Butyl *N*-(benzyloxycarbonyl)-3-amino-4-(2-benzoxazolyl)-4-hydroxy-butanoate (**59**). To a stirred solution of benzoxazole (250.2mg, 2.1mmol) in anhydrous THF (10.5ml) at -78°C under N<sub>2</sub> was added 2.3M *n*-butyl lithium in hexanes (0.96ml, 2.2mmol) dropwise. After stirring at -78°C for 20min, dry MgBr<sub>2</sub>OEt<sub>2</sub> (594.0mg, 2.3mmol) was added as a solid. The resulting heterogeneous mixture was warmed to -45°C and stirred for 15min. The reaction mixture was then recooled to -78°C and a solution of aldehyde **58** (Graybill et al., Int. J. Peptide Protein Res., 44, pp. 173-182 (1993)) (644.6mg, 2.1mmol) in THF (10.5ml) was added dropwise.

The reaction was stirred at -78°C for 30min, warmed to 0°C for 1h, and then stirred at room temperature for 16h. The reaction was quenched with 5% sodium bicarbonate (2.0ml) and the THF was removed in vacuo.

5 The resulting aqueous residue was extracted four times with methylene chloride. The combined extracts were washed with brine, dried (MgSO<sub>4</sub>), filtered and reduced in vacuo to give 880.0mg of crude product. Flash chromatography (45:55 ethyl acetate/hexane) afforded  
10 567.2mg (63%) of the title compound, an oil, as a mixture of diastereoisomers at C-4. IR (film) 3324, 2976, 1726, 1517, 1455, 1368, 1243, 1159, 1048, 747; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.71-7.64 (1H, m), 7.52-7.48 (1H, m), 7.37-7.20 (7H, m), 5.91 (1H, brd, *J* = 9.0), 5.79 (1H, d, *J* = 9.0), 5.41-4.78 (4H, m), 4.75-4.54 (1H, m),  
15 2.91-2.51 (2H, m), 1.42 (9H, s), 1.37 (9H, s).

(3*S*, 4*R*,*S*) *t*-Butyl 3-amino-4-(2-benzoxazolyl)-4-hydroxybutanoate (60). A solution of the ester 59 (189.0mg, 0.44mmol) in ethanol (5.0ml) was treated with  
20 10% Palladium on carbon (20.5mg) and stirred under an atmosphere of H<sub>2</sub> for 21h. The mixture was filtered through Celite®, and the solvent was evaporated to afford 125.0mg (98%) of crude amine 60 as an oil. This was used without further purification. <sup>1</sup>H NMR (CDCl<sub>3</sub>)  
25 δ 7.73-7.64 (1H, m), 7.51-7.42 (1H, m), 7.35-7.22 (2H, m), 6.48 (3H, brs), 5.58 (1H, d, *J* = 3.0), 5.27 (1H, d, *J* = 6.5), 4.23-4.05 (1H, m), 2.92-2.63 (2H, m), 1.36 (9H, s), 1.33 (9H, s).

(3*S*, 4*R*,*S*) *t*-Butyl *N*-(*N*-benzyloxycarbonyl-(*S*)-valinyl-(*S*)-alaninyl)-3-amino-4-(2-benzoxazolyl)-4-hydroxybutanoate (61). A solution of the amine 60 (261.4mg, 0.89mmol), *Z*-Val-Ala-OH (286.9mg, 0.89mmol) (prepared by standard peptide synthetic procedures) and

hydroxybenzotriazole (120.3mg, 0.89mmol) in DMF (3.0ml) at 0°C was treated with 1-ethyl-3-[3-(dimethylamino)propyl]carbodiimide hydrochloride (179.2mg, 0.93mmol). The reaction was warmed to room temperature and stirred for 16h. The reaction was diluted with ethyl acetate and washed twice with 1M sodium hydrogensulphate, twice with saturated sodium bicarbonate, then water, and brine. The organic layer was dried (MgSO<sub>4</sub>), filtered and reduced in vacuo to afford 494.8mg of crude product. Flash chromatography (95:5 methylene chloride/methanol) gave 480.9mg (91%) of the title compound as a yellow solid: mp. 81-83°C; IR (KBr) 3312, 2974, 1723, 1709, 1529, 1455, 1368, 1243, 1156, 747; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.79 (0.5H, d, J = 8.0), 7.73-7.20 (9.5H, m), 6.15 (1H, t, J = 8.5), 5.74 (0.5H, brd, J = 5.5), 5.45 (1H, brd, J = 7.5), 5.28-5.20 (0.5H, m), 4.82-4.11 (3.5H, m), 4.78-4.55 (1H, m), 4.40-4.22 (1H, m), 2.95-2.51 (2H, m), 2.12-1.95 (1H, m), 1.45-1.32 (12H, m), 1.11-0.81 (6H, m), <sup>13</sup>C NMR (CDCl<sub>3</sub>) δ 173.14, 172.94, 171.82, 171.03, 170.78, 165.98, 165.45, 157.29, 157.17, 151.23, 151.10, 140.92, 140.82, 136.83, 136.79, 128.91, 128.52, 125.75, 124.97, 120.60, 120.40, 111.38, 81.82, 81.68, 70.27, 68.97, 67.44, 60.43, 50.74, 50.55, 49.18, 49.07, 36.87, 36.57, 32.37, 28.51, 19.88, 19.80, 18.53. Anal. Calcd. for C<sub>31</sub>H<sub>40</sub>N<sub>4</sub>O<sub>8</sub>. H<sub>2</sub>O: C, 60.57; H, 6.89; N, 9.11. Found: C, 60.84; H, 6.64; N, 9.09. M.S. (+ FAB); 597 (M<sup>+</sup> + 1); 541, 91.

**(3S) t-Butyl N-(N-benzyloxycarbonyl-(S)-valinyl-(S)-alaninyl)-3-amino-4-(2-benzoxazolyl)-4-oxobutanoate (62).** The alcohol 61 (100.3mg, 0.17mmol) was dissolved in methylene chloride (2.0ml) and Dess-Martin reagent (142.6mg, 0.34mmol) was added (Ireland et al., J. Org. Chem., 58, p. 2899 (1993); Dess et al., J. Org. Chem., 48, pp. 4155-4156 (1983)). The resulting mixture was

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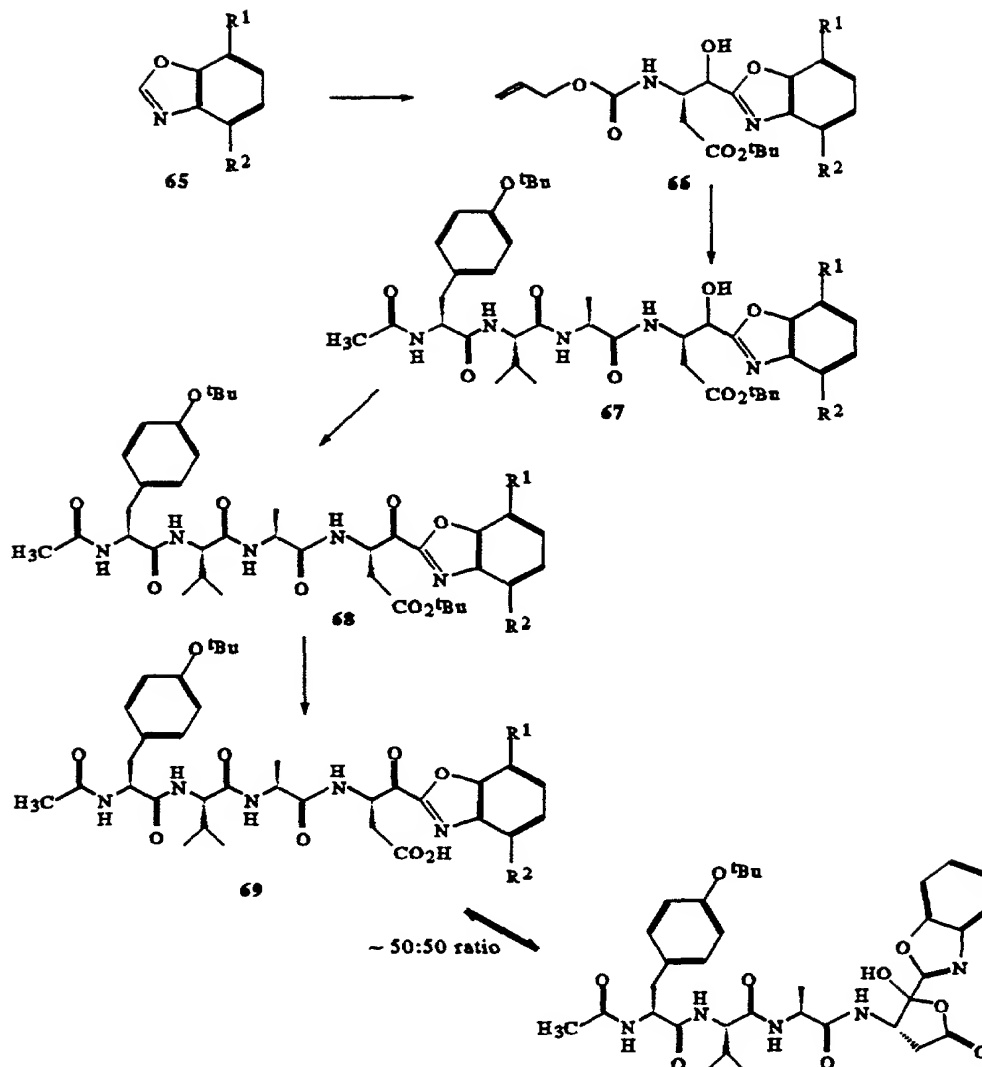
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mixture of three isomers in CD<sub>3</sub>OD, consisting of the ketone form (one isomer, c 44%), and its acycloxy ketal form (two isomers at C-4, c. 56%): m.p. 156-159°C [ $\alpha$ ]<sub>D</sub><sup>26</sup> -45.6° (c 0.13, methanol); IR (KBr) 3440, 2967, 1713, 1703, 1638, 1531, 1427; <sup>1</sup>H NMR (CD<sub>3</sub>OD)  $\delta$  7.93-7.24 (9H, m), 5.59 (1H, brt), 5.16-5.00 (2H, m), 5.0-4.78 (1H, m), 4.50-4.22 (1H, m), 3.95-3.81 (1H, m), 3.11 (2H, d,  $J$  = 6.5), 3.05-2.92 (1H, m), 2.70-2.39 (1H, m), 2.08-1.89 (1H, m), 1.19-0.78 (9H, m). Anal. Calcd. for C<sub>27</sub>H<sub>30</sub>N<sub>4</sub>O<sub>8</sub> · 0.5H<sub>2</sub>O: C, 59.22; H, 5.71; N, 10.23. Found: C, 59.48, H, 5.36, N, 10.17. M.S. (+ FAB); 539 (M<sup>+</sup> + 1), 91.



(a) R<sup>1</sup> = OCH<sub>3</sub>, R<sup>2</sup> = H

(b) R<sup>1</sup> = H, R<sup>2</sup> = OCH<sub>3</sub>

5 7-Methoxybenzoxazole (65a). A mixture of 2-nitro-6-methoxyphenol (2.62g, 15.5mmol) (EP 333176) and 10% Palladium on carbon (130mg) in ethanol (50.0ml) was stirred under an atmosphere of H<sub>2</sub> for 75min. The mixture was filtered through Celite® then immediately treated with *p*-toluenesulphonic acid (32.0mg) and triethylorthoformate (6.45ml, 38.8mmol) then heated

10 under reflux under an atmosphere of N<sub>2</sub>. After 20h *p*-

toluenesulphonic acid (30.0mg) and triethylorthoformate (6.45ml, 38.8mmol) were added. After a total of 44h heating, the reaction was allowed to cool and reduced in vacuo. The resulting residue was purified by flash chromatography (25:75 ethyl acetate/hexane) to give 1.97g (85%) of the title compound as a yellow solid: m.p. 28-31°C; IR (film) 1629, 1497, 1434, 1285, 1097; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 8.09 (1H, s), 7.40 (1H, d, J = 8.0), 7.28 (1H, t, J = 8.0), 6.89 (1H, d, J = 8.0), 4.02 (3H, s); <sup>13</sup>C NMR (CDCl<sub>3</sub>) δ 152.84, 145.82, 142.50, 139.99, 125.75, 113.42, 108.80, 56.97. Anal. Calcd. for C<sub>8</sub>H<sub>7</sub>N<sub>1</sub>O<sub>2</sub>. 0.1H<sub>2</sub>O: C, 63.65; H, 4.81; N, 9.29. Found: C, 63.43, H, 4.88, N, 9.05. M.S. (+ FAB); 150 (M<sup>+</sup> + 1).

**4-Methoxybenzoxazole (65b).** To a suspension of 4-hydroxybenzoxazole (2.00g, 14.8mmol) (Musser et al., J. Med. Chem., 30, pp. 62-67 (1987)) in acetone (80.0ml) was added dried K<sub>2</sub>CO<sub>3</sub> (2.25g, 16.3mmol) followed by iodomethane (1.38ml, 22.2mmol). The reaction was heated under reflux under N<sub>2</sub> for 4.5h, then filtered and reduced in vacuo to afford the crude product. The resulting residue was purified by flash chromatography (25:75 ethyl acetate/hexane) to give 2.0g (91%) of the title compound as a white crystalline solid: m.p. 72-74°C; IR (KBr) 3089, 1619, 1610, 1503, 1496, 1322, 1275, 1090, 1071, 780, 741; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 8.02 (1H, s), 7.32 (1H, t, J = 8.0), 7.18 (1H, d, J = 8.0), 6.81 (1H, d, J = 8.0), 4.04 (3H, s). Anal. Calcd. for C<sub>8</sub>H<sub>7</sub>NO<sub>2</sub>: C, 64.42; H, 4.73; N, 9.39. Found: C, 64.40; H, 4.84; N, 9.31; m/z (EI) 149 (M<sup>+</sup> + 1, 100%).

**(3S, 4R,S) t-Butyl N-(allyloxycarbonyl)-3-amino-4-hydroxy-4-(2-(7-methoxybenzoxazolyl))butanoate (66a).** To a stirred solution of 7-methoxybenzoxazole 65a (548.6mg, 3.68mmol) in anhydrous THF (18.5ml) at -78°C

under N<sub>2</sub> was added 1.56M *n*-butyl lithium in hexanes (2.47ml, 3.86mmol) dropwise, to produce a yellow colored solution. After stirring at -78°C for 20 min, dry MgBr<sub>2</sub>OEt<sub>2</sub> (1.045g, 4.05mmol) was added as a solid.

5 The resulting heterogeneous mixture was warmed to -45°C and stirred for 15min. The reaction mixture was then recooled to -78°C and a solution of (S)-Alloc-Asp(*t*-Bu)H<sup>1b</sup> (946.4mg, 3.68mmol) in THF (18.5ml) was added dropwise. The reaction was stirred at -78°C for 30min,

10 warmed to 0°C and stirred for 1h. The resulting homogeneous reaction was warmed to room temperature and stirred for 16h. The reaction was quenched with 5% sodium bicarbonate (3.5ml) then THF was removed in vacuo. The resulting aqueous residue was extracted

15 with methylene chloride (x6). The combined extracts were washed with brine, dried (MgSO<sub>4</sub>), filtered and reduced in vacuo to give 1.8g of crude product. Flash chromatography (40:60 ethyl acetate/hexane) gave 1.21g (81%) of the title compound, an oil, as a mixture of diastereoisomers at C-4: IR (CH<sub>2</sub>Cl<sub>2</sub>) 3425, 2983, 1725, 1504, 1290, 1157, 1101; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.35-7.19 (2H, m), 6.89-6.81 (1H, m), 6.00-5.57 (2H, m), 5.32-5.05 (3H, m), 4.68-4.35 (3H, m), 4.01 (3H, s), 2.86-2.59 (2H, m), 1.45 (9H, s), 1.41 (9H, s); <sup>13</sup>C NMR (CDCl<sub>3</sub>) δ

20 171.18, 171.09, 165.80, 165.30, 156.71, 156.60, 145.65, 142.76, 142.71, 140.82, 140.72, 133.23, 125.81, 125.72, 118.41, 118.21, 113.07, 112.87, 108.95, 82.16, 70.28, 69.98, 66.52, 66.39, 57.03, 52.57, 52.29, 37.83, 36.86, 28.65. Anal. Calcd. for C<sub>20</sub>H<sub>26</sub>N<sub>2</sub>O<sub>7</sub> · 0.6H<sub>2</sub>O: C, 57.57; H, 6.57; N, 6.72. Found: C, 57.49, H, 6.34, N, 6.60. M.S. (+ FAB); 407 (M<sup>+</sup> + 1); 351, 307, 154.

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(3*S*, 4*R*, *S*) *t*-Butyl N-(allyloxycarbonyl)-3-amino-4-hydroxy-4-(2-(4-methoxybenzoxazolyl))butanoate (66b), was prepared according to the method described for 66a

which afforded 1.29g (26%, 68% based on recovered starting material) of the title compound as an oil and as a mixture of diastereoisomers at C-4: IR (CH<sub>2</sub>Cl<sub>2</sub>) 3400, 1725, 1625, 1505, 1369, 1354, 1281, 1263, 1226, 1158, 1092, 1048; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.34-7.24 (1H, m), 7.16 (1H, d, J = 8.2), 6.79 (1H, d, J = 7.9), 6.00-5.50 (2H, m), 5.30-5.05 (3H, m), 4.70-4.35 (4H, m), 4.02 (3H, s), 2.90-2.45 (2H, m), 1.45-1.41 (9H, 2 x s). Anal. Calcd. for C<sub>20</sub>H<sub>26</sub>N<sub>2</sub>O<sub>7</sub> · 0.4H<sub>2</sub>O: C, 58.07; H, 6.53; N, 6.77. Found: C, 58.09; H, 6.41; N, 6.63. M.S. (+ FAB); 407 (M<sup>+</sup> + 1, 88%); 351 (100).

(3*S*, 4*R*,*S*) t-Butyl N-(N-acetyl-(*S*)-(O-tert-butyl-tyrosinyl)-(*S*)-valinyl-(*S*)-alaninyl)-3-amino-4-hydroxy-4-(2-(7-methoxybenzoxazolyl))butanoate (67a). To a stirred solution of the benzoxazole 66a (481.9mg, 1.19mmol) and Ac-Tyr(<sup>t</sup>Bu)-Val-Ala-OH (586.3mg, 1.30mmol) in methylene chloride (3.5ml) and DMF (3.5ml) was added bis(triphenylphosphine) palladium (II) chloride (18.0mg), followed by tributyltinhydride (0.80ml, 2.96mmol) dropwise. Hydroxybenzotriazole (320.4mg, 2.37mmol) was added and the mixture cooled to 0°C. 1-Ethyl-3-[3-(dimethylamino)propyl]carbodiimide hydrochloride (278.2mg, 1.42mmol) was added and the mixture was allowed to warm to room temperature and stirred for 16.5h. The reaction was diluted with ethyl acetate and washed twice with 1M sodium hydrogensulphate, twice with saturated sodium bicarbonate, water, and brine. The organic layer was dried (MgSO<sub>4</sub>), filtered and reduced *in vacuo* to yield 2.0g of crude product. Flash chromatography (95:5 methylene chloride/methanol) gave 844.0mg (94%) of the title compound as a white solid: m.p. 205°C; IR (KBr) 3399, 3304, 2977, 1729, 1643, 1506, 1367, 1290, 1161; <sup>1</sup>H NMR (d<sub>6</sub>-DMSO) δ 8.24-7.78 (4H, m), 7.43-7.32 (2H, m),

7.23 (2H, d,  $J = 8.5$ ), 7.16-7.07 (1H, m), 6.93 (2H, d,  $J = 8.5$ ), 6.52, 6.40 (1H, 2 x d,  $J = 5.5$ ,  $J = 5.0$ ), 5.03, 4.78-4.49, 4.45-4.16 (5H, brt, 2 x m), 4.05, 4.04 (3H, 2 x s), 3.08-2.35 (14H, m), 2.11-1.89 (1H, m), 1.83 (3H, s), 1.49-1.32, 1.15, 1.0-0.81 (27H, s, 2 x m,  $J = 7.0$ );  $^{13}\text{C}$  NMR ( $\text{d}_6$ -DMSO)  $\delta$  175.55, 175.18, 173.88, 173.75, 173.05, 169.23, 157.28, 148.55, 146.16, 143.21, 136.63, 133.55, 128.87, 127.17, 115.78, 111.92, 84.02, 81.50, 71.40, 61.15, 60.05, 57.79, 53.39, 51.62, 43.76, 40.52, 34.58, 32.52, 31.60, 26.35, 23.11, 22.71, 21.76. Anal. Calcd. for  $\text{C}_{39}\text{H}_{55}\text{N}_5\text{O}_{10}$ .  $0.5\text{H}_2\text{O}$ : C, 61.40; H, 7.40; N, 9.18. Found: C, 61.43; H, 7.31; N, 9.07. M.S. (+ FAB); 754 ( $\text{M}^+ + 1$ ); 698, 338, 267.

(3*S*, 4*R*, *S*) *t*-Butyl *N*-(*N*-acetyl-(*S*)-(O-*tert*-butyl-tyrosinyl)-(*S*)-valinyl-(*S*)-alaninyl)-3-amino-4-hydroxy-4-(2-(4-methoxybenzoxazolyl))butanoate (67b), was prepared according to the method described for 67a which afforded 1.05g (94%) of the title compound as a fine white powder: m.p. 210-213°C (dec); IR (KBr) 3284, 2977, 1736, 1691, 1632, 1536, 1505, 1452, 1392, 1367, 1258, 1236, 1161, 1091;  $^1\text{H}$  NMR ( $\text{d}_6$ -DMSO)  $\delta$  8.20-7.75 (4H, m), 7.40-7.10 (4H, m), 7.00-6.80 (3H, m), 6.45, 6.34 (1H, 2 x d,  $J = 5.3$ ,  $J = 5.0$ ), 5.00-4.10 (5H, m), 4.00, 3.99 (3H, 2 x s), 3.00-2.25 (4H, m), 1.95 (1H, m), 1.78 (3H, s), 1.39-0.80 (27H, m). Anal. Calcd. for  $\text{C}_{39}\text{H}_{55}\text{N}_5\text{O}_{10}$ .  $0.5\text{H}_2\text{O}$ : C, 61.40; H, 7.40; N, 9.18. Found: C, 61.58; H, 7.38; N, 8.91. M.S. (+ FAB); 754 ( $\text{M}^+ + 1$ , 30%); 72 (100).

(3*S*) *t*-Butyl *N*-(*N*-acetyl-(*S*)-(O-*tert*-butyl-tyrosinyl)-(*S*)-valinyl-(*S*)-alaninyl)-3-amino-4-(2-(7-methoxybenzoxazolyl))-4-oxobutanoate (68a). The Dess-Martin reagent (1.082g, 2.55mmol) (Ireland et al., *J. Org. Chem.*, 58, p. 2899 (1993); Dess et al., *J. Org.*

Chem., 48, pp. 4155-4156 (1983)) was added to a stirred suspension of the alcohol 67a (641.0mg, 0.85mmol) in methylene chloride (46.0ml). The resulting mixture was stirred for 1h before being partitioned between saturated sodium thiosulphate: saturated sodium bicarbonate (1:1, 86.0ml) and ethyl acetate (86.0ml). The resultant organic phase was washed in turn with saturated sodium thiosulphate: saturated sodium bicarbonate (1:1), saturated sodium bicarbonate, and brine. The organic phase was dried (MgSO<sub>4</sub>), filtered and reduced in vacuo to give 660.0mg of crude product. Flash chromatography (94:6 methylene chloride/methanol) gave 636.0mg (100%) of the title compound as a white solid: m.p. 209°C; [α]<sub>D</sub><sup>24</sup> -21.8° (c 0.16, methanol); IR (KBr) 3395, 3294, 2977, 1722, 1641, 1535, 1505, 1161; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 8.43-8.16 (1H, m), 7.97-7.62 (2H, m), 7.49-7.14 (3H, m), 7.08-6.95 (3H, m), 6.89-6.73 (2H, m), 5.81-5.68 (1H, m), 5.16-4.86 (2H, m), 4.53 (1H, brt), 4.03 (3H, s), 3.16-2.84 (4H, m), 2.11-1.84 (4H, m), 1.46-1.14 (21H, m), 0.92-0.78 (6H, m); <sup>13</sup>C NMR (CDCl<sub>3</sub>) δ 186.28, 173.39, 171.90, 171.19, 171.03, 169.89, 156.43, 154.75, 146.32, 142.88, 140.98, 132.31, 130.54, 126.98, 124.73, 114.95, 111.42, 82.44, 78.71, 58.92, 57.20, 54.91, 53.47, 48.77, 39.43, 38.15, 32.79, 29.44, 28.60, 23.55, 20.27, 19.70, 19.34. M.S. (+ FAB); 752 (M<sup>+</sup> + 1); 696, 336, 265.

(3S) t-Butyl N-(N-acetyl-(S)-(O)-tert-butyl-tyrosinyl)-(S)-valinyl-(S)-alaninyl)-3-amino-4-(2-(4-methoxybenzoxazolyl))-4-oxobutanoate (68b), was prepared according to the method described for the ketone 68a which afforded 420mg (55%) of the title compound as a white solid: m.p. 211-213°C (dec); [α]<sub>D</sub><sup>24</sup> -23.9° (c 0.82, methanol); IR (KBr) 3277, 3075, 1723, 1690, 1632, 1530, 1506, 1392, 1366, 1269, 1234, 1160,

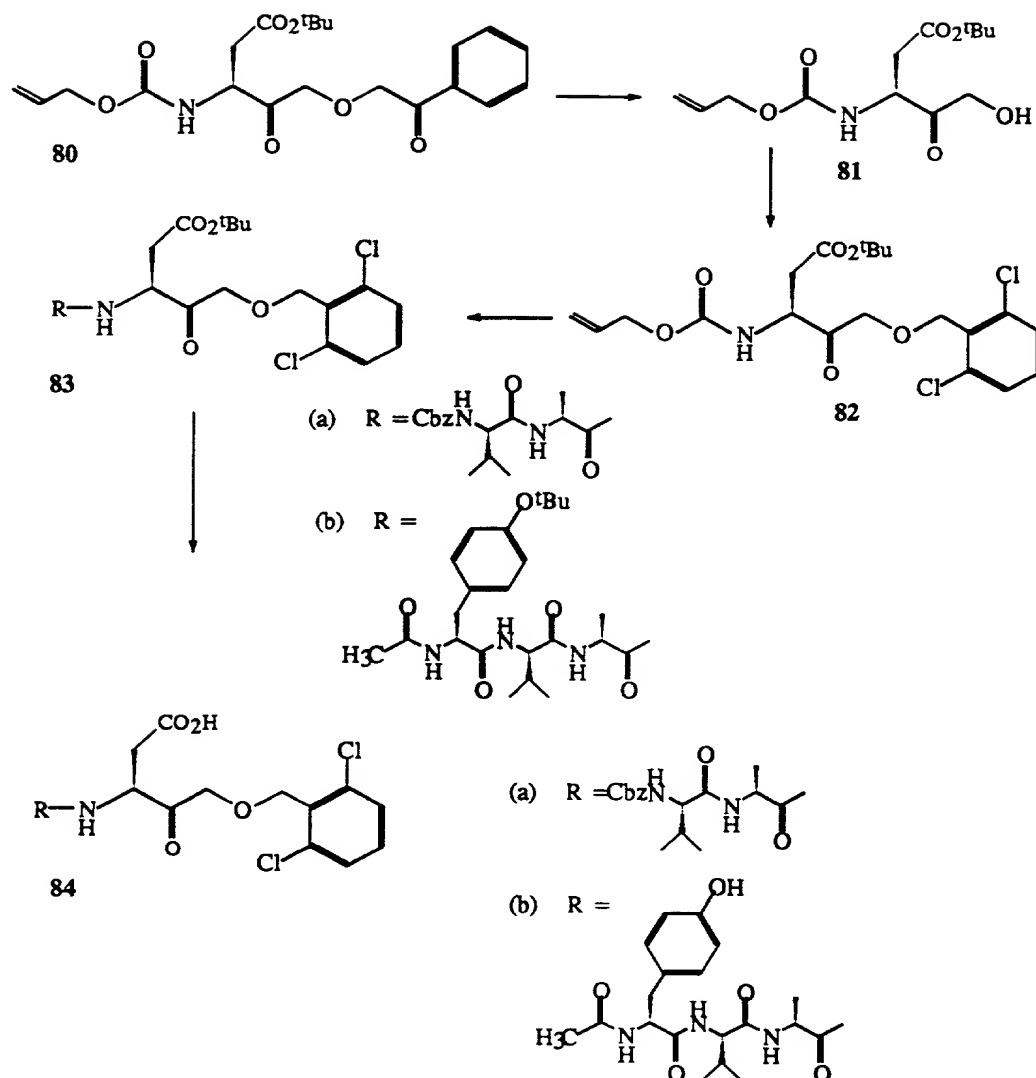
1094; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 8.15 (1H, brs), 7.7 (2H, brs), 7.46 (1H, t, *J* = 8.3), 7.24 (2H, d, *J* = 8.3), 7.10 (1H, brs), 7.03 (2H, d, *J* = 8.3), 6.83 (3H, m), 5.74 (1H, q, *J* = 6.9), 5.00 (2H, m), 4.51 (1H, t, *J* = 7.0), 4.07 (3H, s), 3.20-2.95 (4H, m), 2.00 (4H, m), 1.42 (3H, d, *J* = 6.8), 1.35 (9H, s), 1.23 (9H, s), 0.86 (6H, d, *J* = 6.7). M.S. (+ FAB); 752 (*M*<sup>+</sup> + 1, 7%); 72 (100).

(3*S*) N-(N-Acetyl-(*S*)-tyrosinyl-(*S*)-valinyl-(*S*)-alaninyl)-3-amino-4-(2-(7-methoxybenzoxazolyl))-4-oxobutanoate (69a; **R**). A solution of the ester 68a (600.0mg, 0.80mmol) in a 1:1 mixture of methylene chloride and trifluoroacetic acid (65.0ml) was stirred for 1h under a dry atmosphere of N<sub>2</sub>. The solution was then reduced in vacuo, taken up in ether and reduced again. This process was repeated six times to afford the crude product as an off white solid. Flash chromatography (gradient 95:5 to 80:20 methylene chloride/methanol) gave 420.8mg (83%) of the title compound as a hygroscopic white solid. The product existed as a mixture of three isomers in CD<sub>3</sub>OD, consisting of the keto form (c 50%), and its acycloxy keto form (two isomers at C-4, c 50%): m.p. decomposes above 150°C; [α]<sub>D</sub><sup>24</sup>-33.2° (c 0.17, methanol); IR (KBr) 3300, 1715, 1658, 1650, 1531, 1517, 1204; <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 7.46-7.19 (2H, m), 7.16-6.91 (3H, m), 6.70-6.59 (2H, m), 5.62-5.49 (1H, m), 5.00-4.72 (1H, obscured m), 4.69-4.51 (1H, m), 4.49-4.08 (2H, m), 4.05-3.89 (3H, m), 3.16-2.47 (4H, m), 2.05-1.78 (4H, m), 1.41-1.11, 1.05-0.70 (9H, 2 x m). Anal. Calcd. for C<sub>31</sub>H<sub>37</sub>N<sub>5</sub>O<sub>10</sub>·3H<sub>2</sub>O: C, 53.67; H, 6.25; N, 10.10. Found: C, 53.76; H, 5.56; N, 10.28. M.S. (+ FAB); 640 (*M*<sup>+</sup> + 1); 435, 147.

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(3*S*) t-Butyl N-(N-acetyl-(*S*)-tyrosinyl-(*S*)-valinyl-(*S*)-alaninyl)-3-amino-4-(2-(4-methoxybenzoxazolyl))-4-oxobutanoate (69b; 5), was prepared according to the method described for the acid 69a which afforded the hygroscopic title compound 252mg (96%). The product existed as a mixture of three isomers in CD<sub>3</sub>OD, consisting of the keto form, and its acycloxy ketal form (two isomers at C-4). The product existed as a single isomer in d-6 DMSO: m.p. 200-203°C (dec.);  $[\alpha]_D^{24}$  -38.0° (c 0.23, methanol); IR (KBr) 3289, 2968, 1718, 1713, 1658, 1634, 1548, 1517, 1506, 1461, 1453, 1393, 1369, 1268, 1228, 1174, 1092; <sup>1</sup>H NMR (d<sub>6</sub>-DMSO)  $\delta$  9.20 (1H, brs), 8.71 (1H, d, *J* = 6.2), 8.10 (2H, m), 7.83 (1H, d, *J* = 8.7), 7.61 (1H, t, *J* = 8.2), 7.46 (1H, d, *J* = 8.2), 7.08 (3H, m), 6.65 (2H, d, *J* = 8.3), 5.50 (1H, q, *J* = 6.5), 4.50 (1H, m), 4.37 (1H, m), 4.20 (1H, m), 4.05 (3H, s), 3.09-2.77 (4H, m), 1.94 (1H, m), 1.79 (3H, s), 1.23 (3H, d, *J* = 7.0), 0.82 (6H, m). Anal. Calcd. for C<sub>31</sub>H<sub>37</sub>N<sub>5</sub>O<sub>10</sub> · 1.5H<sub>2</sub>O: C, 55.85; H, 6.05; N, 10.51. Found: C, 55.21; H, 5.69; N, 10.13. M.S. (+ FAB); 640 (M<sup>+</sup> + 1, 22%); 107 (100).



5

3S) t-Butyl N-(allyloxycarbonyl)-3-amino-4-oxo-5-(1,2-dioxo-2-phenylethyloxy)-pentanoate (80). Potassium fluoride (792mg, 13.6mmol) and then benzoyl formic acid (1.02g, 6.82mmol) were added to a stirred solution of (3S) t-butyl N-(allyloxycarbonyl)-3-amino-5-bromo-4-oxo-pentanoate (WO 93 16710) (2.17g, 6.20mmol) in dimethylformamide (30ml). The mixture was stirred for 140 mins, quenched with water (50ml) and extracted with

ethyl acetate (2 x 50ml). The combined organic extracts were washed with water (4 x 50ml) then brine (50ml). They were dried (MgSO<sub>4</sub>) and concentrated to afford an oil which was purified by flash chromatography (20-45% ethyl acetate in hexane) to afford 2.44g (94%) of a colorless oil:  $[\alpha]_D^{20}$  -35.0° (c 1.41, CH<sub>2</sub>Cl<sub>2</sub>); IR (film) 3359, 2981, 2938, 1752, 1740, 1726, 1712, 1512, 1369, 1285, 1177, 1053, 991, 939, 688; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 8.15 (2H, m), 7.66 (1H, m), 7.53 (2H, m), 5.90 (2H, m), 5.33 (2H, m), 5.31 (1H, d, J = 16.9), 5.18 (1H, d, J = 16.9), 4.63 (3H, m), 3.03 (1H, dd, J = 17.3, 4.6), 2.74 (1H, dd, J = 17.3, 4.9), 1.44 (9H, s). MS (C.I.) 420 (M<sup>+</sup> + 1 20%); 364 (100).

(3S) t-Butyl N-(allyloxycarbonyl)-3-amino-5-hydroxy-4-oxo-pentanoate (81). A mixture of the ester 80 (2.40g, 5.71mmol), tetrahydrofuran (200ml) and 1M aqueous potassium bicarbonate (200ml) was vigorously stirred at room temperature for 18h. The layers were separated and the aqueous portion extracted with ethyl acetate (100ml). The combined organic extracts were washed with brine (100ml), dried (MgSO<sub>4</sub>) and concentrated. The residue was purified by flash chromatography (10-60% ethyl acetate in hexane) to afford 1.48g (90%) of pale yellow oil:  $[\alpha]_D^{20}$  -5.9° (c 1.06, CH<sub>2</sub>Cl<sub>2</sub>); IR (film) 3345, 2981, 2936, 1739, 1725, 1712, 1692, 1515, 1368, 1259, 1158, 1051; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 5.92 (2H, m), 5.30 (2H, m), 4.36-4.69 (5H, m), 3.05 (1H, dd, J = 17.4, 4.3), 2.93 (1H, t), 2.70 (1H, dd, J = 17.4, 4.9), 1.43 (9H, s). Anal. Calcd for C<sub>18</sub>H<sub>21</sub>N<sub>1</sub>O<sub>6</sub>. 0.25H<sub>2</sub>O: C, 53.51; H, 7.43; N, 4.80. Found: C, 53.61; H, 7.18; N, 4.71. MS (C.I.) 280 (M<sup>+</sup> + 1, 87%); 232 (100).

(3S) t-Butyl N-(allyloxycarbonyl)-3-amino-5-(2,6-dichlorophenyl-methoxy)-4-oxo-pentanoate (82). A stirred mixture of alcohol 81 (1.44g, 5.01mmol), 2,6-dichlorobenzyl iodide (Abraham et al., J. Chem. Soc., pp. 1605-1607 (1936)) (4.31g, 15.0mmol), silver oxide (2.32g, 10.0mmol) and dichloromethane (25ml) was heated under reflux for 45h. The mixture was allowed to cool to room temperature then diluted with water (50ml) then extracted with ethyl acetate (50ml, 25ml). The organic layer was washed with water (50ml) then brine (50ml), dried (MgSO<sub>4</sub>), and concentrated. The residue was purified by flash chromatography (10-100% ethyl acetate in hexane) to afford 1.65g (74%) of a colorless oil:  $[\alpha]_D^{20} +8.8^\circ$  (c 1.13, CH<sub>2</sub>Cl<sub>2</sub>); IR (film) 3339, 2980, 2935, 1724, 1712, 1503, 1438, 1368, 1246, 1156, 1106, 770; <sup>1</sup>H NMR (CDCl<sub>3</sub>)  $\delta$  7.33 (2H, m), 7.22 (1H, dd), 5.92 (2H, m), 5.28 (2H, m), 4.87 (2H, m), 4.67 (1H, m), 4.58 (2H, br d), 4.56 (1H, d,  $J = 16.9$ ), 4.31 (1H, d,  $J = 16.9$ ), 3.04 (1H, dd,  $J = 16.7, 4.5$ ), 2.77 (1H, dd,  $J = 16.7, 4.9$ ), 1.40 (9H, s). Anal. Calcd. for C<sub>20</sub>H<sub>25</sub>Cl<sub>2</sub>N<sub>1</sub>O<sub>6</sub> · 0.25H<sub>2</sub>O: C, 53.28; H, 5.70; N, 3.11. Found: C, 53.15; H, 5.52; N, 2.98. M.S. (C.I.); 446 (M<sup>+</sup>, 27%); 390 (100).

(3R,S) t-Butyl N-[N-phenylmethyloxycarbonylvalaninyl-alaninyl]-3-amino-5-(2,6-dichlorophenylmethoxy)-4-oxo-pentanoate (83a). 1-(3-Dimethylamino-propyl)-3-ethylcarbodiimide hydrochloride (379g, 1.98mmol) and 1-hydroxybenzotriazole (486mg, 3.60mmol) were added to a stirred solution of N-phenyl-methyloxycarbonylvalinyl-alanine (637mg, 1.98mmol) in tetrahydrofuran (40ml) and water (1ml). The mixture was stirred for 15mins and then the ether 82 (802mg, 1.80mmol) and bis(triphenylphosphine)palladium (II) chloride (ca 5mg) were added.

Tributyltin hydride (785mg, 725  $\mu$ l, 2.70mmol) was then added dropwise during 20mins and the resulting solution was stirred for 3.75h and then quenched with 1M hydrochloric acid (50ml). The mixture was extracted  
5 twice with ethyl acetate. The combined organic extracts were washed with 1M hydrochloric acid, twice with aqueous sodium bicarbonate, water and then brine, dried (MgSO<sub>4</sub>) and concentrated. The residue was purified by flash chromatography (10-30% ethyl acetate  
10 - dichloromethane) to afford 941mg (79%) of pale yellow solid: m.p. 148-52°C; IR (KBr) 3287, 3070, 1730, 1691, 1641, 1536, 1369, 1289, 1247, 1156; <sup>1</sup>H NMR (CDCl<sub>3</sub>)  $\delta$  7.33 (8H, m), 7.23 (1H, dd), 6.61 (1H, br, d), 5.42 (1H, br, d), 5.11 (2H, s), 4.85 (3H, m), 4.50 (1H, m),  
15 4.40 (1H, d, *J* = 16.9), 4.26 (1H, d, *J* = 16.9), 4.02 (1H, m), 2.99 (1H, dd, *J* = 16.8, 4.7), 2.73 (1H, dd, *J* = 16.8, 5.0), 2.09 (1H, m), 1.37 (12H, m), 0.96 (3H, d, *J* = 6.9), 0.91 (3H, d, *J* = 6.8). Anal. Calcd. for C<sub>32</sub>H<sub>41</sub>Cl<sub>2</sub>N<sub>3</sub>O<sub>8</sub> · 0.25H<sub>2</sub>O: C, 57.25; H, 6.23; Cl, 10.57; N, 6.26. Found: C, 57.18; H, 6.23; Cl, 10.58; N, 5.95.  
20 M.S. (+ FAB); 667 (M<sup>+</sup> 1, 1%); 666 (3), 159 (25), 91 (100).

**(3R,S) t-Butyl N-[(N-acetyl-O-t-butyltyrosinyl)-valaninyl-alaninyl]-3-amino-5-(2,6-dichlorophenylmethyloxy)-4-oxo-pentanoate (83b)**, was  
25 prepared by the method described for 83a to afford 554mg (64%) of colorless solid: m.p. 184-6°C; IR (KBr) 3282, 3075, 1736, 1690, 1633, 1536, 1508, 1366, 1236, 1161; <sup>1</sup>H NMR (d<sub>6</sub>-DMSO)  $\delta$  8.49 (1H, d), 8.14 (1H, d),  
30 8.08 (1H, d), 7.84 (1H, d), 7.43 (3H, m), 7.14 (2H, d), 6.83 (2H, d), 4.71 (2H, s), 4.51 (2H, m), 4.36 (2H, dd), 4.17 (2H, m), 2.93 (1H, m), 2.73 (1H, m), 1.94 (1H, m), 1.74 (3H, s), 1.37 (9H, s), 1.23 (12H, m),

0.83 (6H, m). M.S. (+ FAB); 793 ( $M^+$  1, 4%); 737 (5), 681 (1), 178 (40), 159 (45), 136 (100), 107 (40). M.S. (- FAB); 792 (20), 791 (40), 447 (100).

5 (R,S) N-[N-(Phenylmethyloxy)carbonyl-valinyl-alaninyl]-  
3-amino-5-(2,6-dichlorophenylmethyloxy)-4-oxo-pentanoic  
acid (84a; Y). Trifluoroacetic acid (5ml) was added to  
a stirred solution of the ester 83a, (918mg, 1.38mmol)  
in dichloromethane (20ml). The mixture was stirred for  
2.5h then evaporated to dryness. The residue was  
10 treated with ether (25ml) and evaporated to dryness.  
This procedure was repeated three times. The resulting  
product was triturated with ether (10ml) and then dried  
to afford 730mg (87%) of light brown powder: m.p. 156-  
60°C; IR (KBr) 3282, 2965, 1702, 1694, 1642, 1536,  
15 1438, 1246, 1230;  $^1\text{H}$  NMR ( $d_6$ -DMSO)  $\delta$  8.48 (1H, d), 8.09  
(1H, d), 7.47 (9H, m), 5.02 (2H, s), 4.70 (2H, s), 4.49  
(1H, m), 4.37 (2H, dd), 4.27 (1H, m), 3.88 (1H, m),  
2.75 (1H, dd), 2.54 (1H, dd), 1.96 (1H, m), 1.19 (3H,  
s), 0.84 (6H, m). Anal. Calcd. for  $\text{C}_{28}\text{H}_{33}\text{Cl}_2\text{N}_3\text{O}_8 \cdot 0.5\text{H}_2\text{O}$ :  
20 C, 54.27; H, 5.53; Cl, 11.45; N, 6.78. Found: C,  
54.49; H, 5.39; Cl, 11.33; N, 6.73. M.S. (+ FAB); 610  
( $M^+$  1, 10%); 91 (100).

25 (R,S) N-[N-(Acetyl)tyrosinyl-valinyl-alaninyl]-3-amino-  
5-(2,6-dichlorophenylmethyloxy)-4-oxo-pentanoic acid  
(84b; W), was obtained as a colorless powder (95%) by  
the method used for 84a. m.p. 165-8°C: IR (KBr) 3295,  
2968, 1733, 1642, 1517, 1438, 1231, 1105;  $^1\text{H}$  NMR ( $d_6$ -  
DMSO) 9.2 (1H, br, s), 8.48 (1H, br, d), 8.14 (1H,  
br, d), 8.02 (1H, br, d), 7.81 (1H, br, d), 7.45 (3H,  
30 m), 7.02 (2H, d), 6.62 (2H, d), 4.70 (2H, s), 4.12-4.53  
(3H, m), 3.60 (3H, m), 2.51-2.92 (4H, m), 1.96 (1H, m),  
1.75 (3H, s), 1.21 (3H, d), 0.83 (6H, m). Anal. Calcd.

for  $C_{31}H_{38}Cl_2N_4O_9$ .  $H_2O$ : C, 53.22; H, 5.76; Cl, 10.14; N, 8.09. Found: C, 53.33; H, 5.54; Cl, 10.02; N, 7.85. M.S. (+ FAB); 682 ( $M^+$  2, 30%); 681 (67), 158 (100). (- FAB); 680 (45), 679 (100).

5

Example 6

We obtained inhibition constants ( $K_i$ ) and  $IC_{50}$  values for several compounds of this invention using enzyme assays with UV-visible substrate, fluorescent substrate, and cell assays as described in Example 2.

10 The following  $K_i$  and  $IC_{50}$  values were determined for compounds 22e, 54b, 54j, 54k, 57b, 85, 86, 87, 88, 89, 90, 91, 92, 98, 102a-c, 106a-c, 108a-c, 114a, 114b, 115, 121, 125a, 125b, 126, 127, 128, 129, 130, 131, 132a, 132b, 133, 135a, 135b, 136, 137, 138, 139, 140, 15  
141, 142, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, and 163 using the indicated assays. The structures of compounds 22e, 54b, 54j, 54k, and 57b are shown in Example 5. The other compound structures are shown in  
20 Example 7.

<u>Assay</u>			
<u>Compound</u>		<u>UV-visible</u>	<u>Cell</u>
		$K_i$ ( $\mu M$ )	$IC_{50}$ ( $\mu M$ )
25	22e	0.19	>20
	54b		20
	54j		10
	54k		6.6
	57b		2.2
30	85	0.0035	9.8

	86	0.175	4.0
	87	7.2	35.0
	88	0.9	
	89	0.018	
5	90	0.42	6.2
	91	0.26	>25
	92	3.8	
	98	0.535	4.0
	102a		4.0
10	102b	0.29	1.75
	102c	0.68	
	106a	2.3	30.0
	106b	0.2	2.9
	106c	3.8	>30.0
15	108a		17.5
	108b	0.4	25.0
	108c	0.43	
	114a	0.12	3.8
	114b	3.7	
20	115	0.345	6.0
	121	4.3	
	125a	0.39	>30.0
	125b	0.060	0.30
	126	0.45	1.5
25	127	0.39	8.0
	128	0.04	7.5
	129	0.59	25.0
	130		1.20
	131	12.0	30.0
30	132a	5.0	>30.0
	132b	12.5	
	133	50.0	>30.0
	135a	0.090	0.90
	135b	0.32	0.95

09086773-063404  
TOT390" E2498860

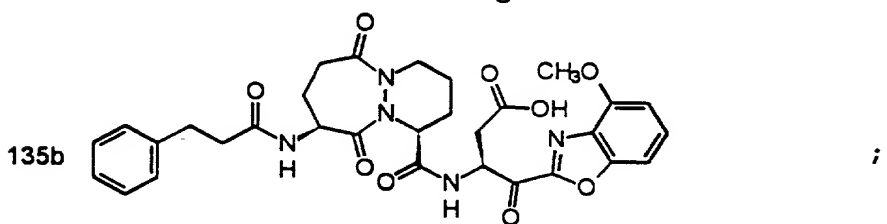
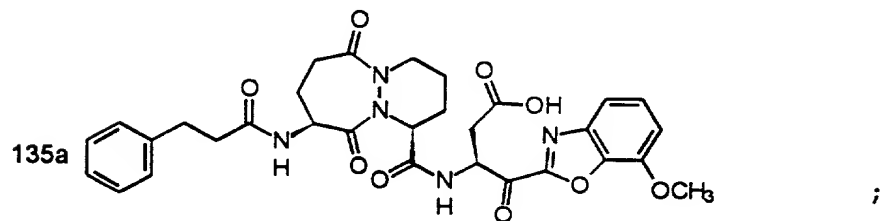
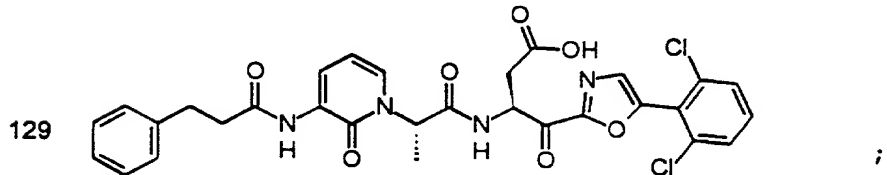


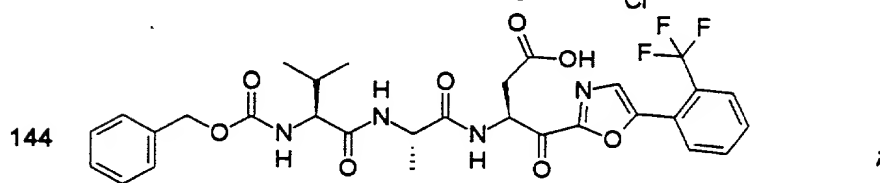
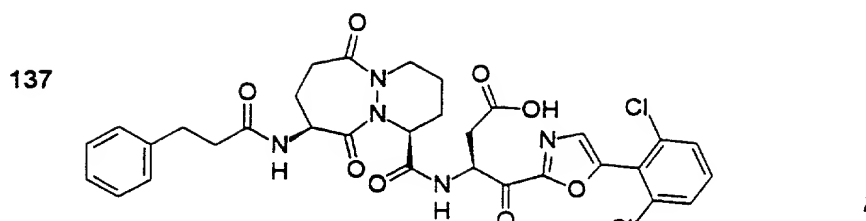
	136		1.0
	137	0.04	0.25
	138		0.375
	139	0.350	2.0
5	140	0.87	>30.0
	141	0.670	
	142		1.75
	144	0.32	>20.0
	145	0.34	8.5
10	146	0.16	3.8
	147	0.26	8.5
	148	6.3	30.0
	149	14.0	>30.0
	150	10.0	30.0
15	151	13.0	30.0
	152	8.8	
	153	0.24	
	154	0.042	2.4
	155	0.023	
20	156	0.001	2.7
	157	0.26	
	158	1.1	
	159	0.0017	8.0
	160	0.145	2.25
25	161	0.011	
	162	0.0025	
	163	0.0028	1.2

Example 7

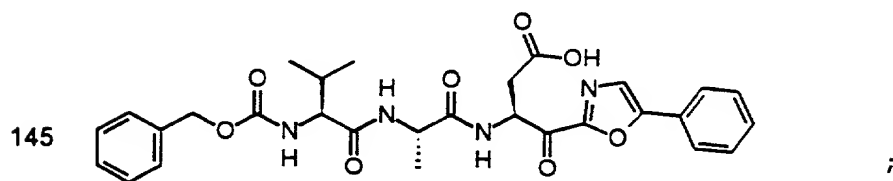
30                    Compounds 126, 127, 128, 129, 135a, 135b, 137  
144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154,  
155, 156, 157, 159, 160, 162, and 163 were synthesized

5

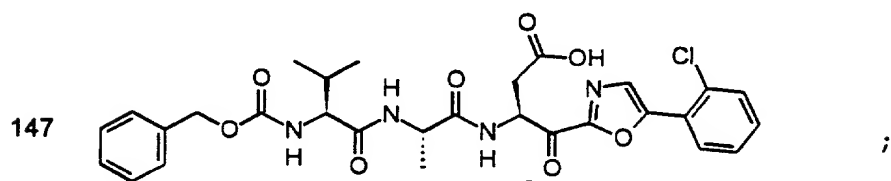
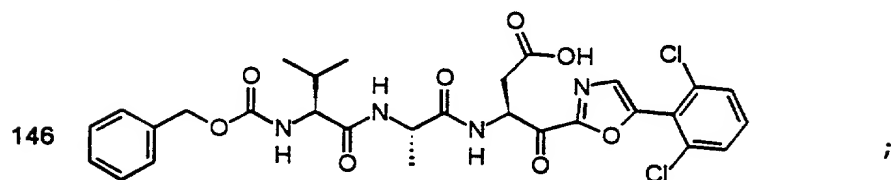




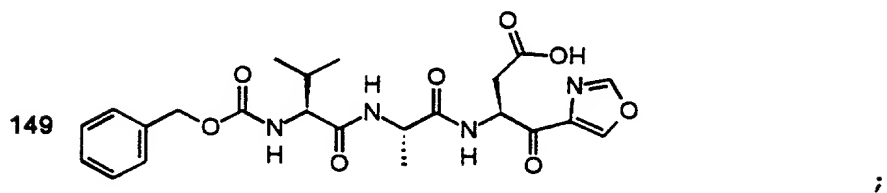
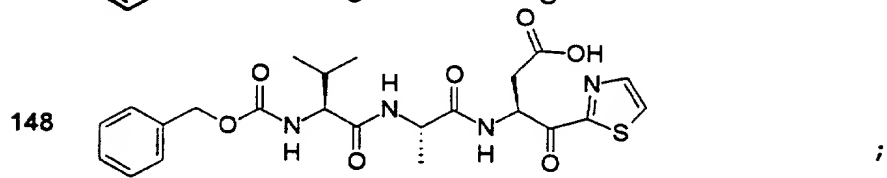
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10

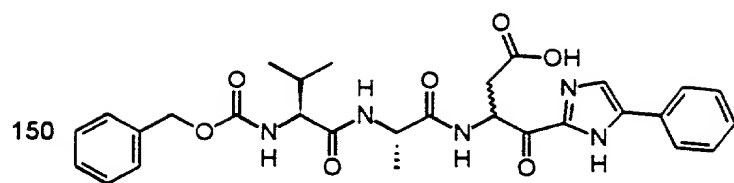


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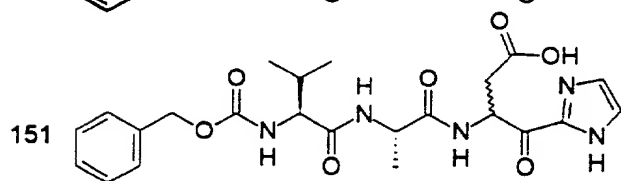


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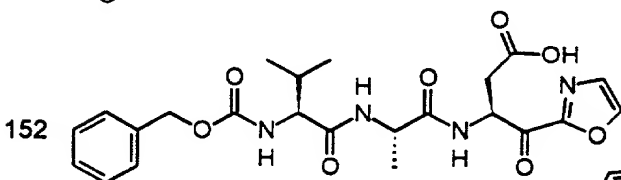
0000677-06101



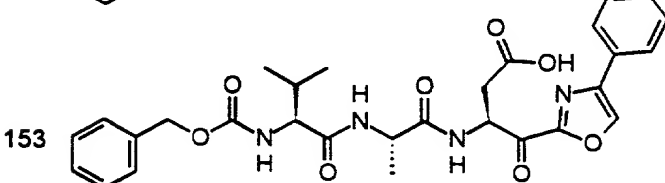
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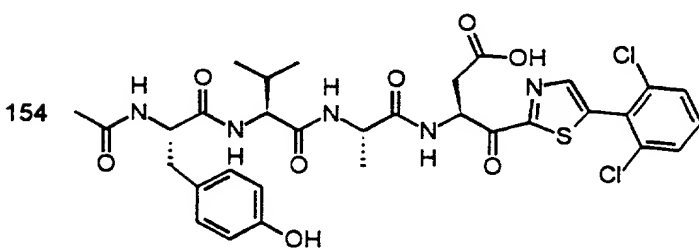
;



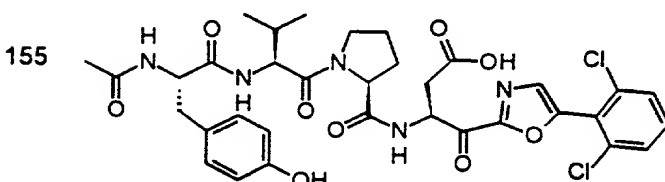
;



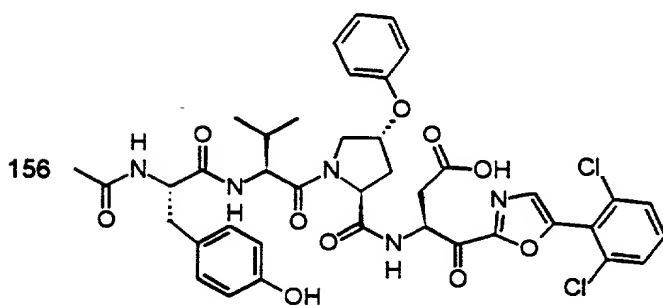
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;



;

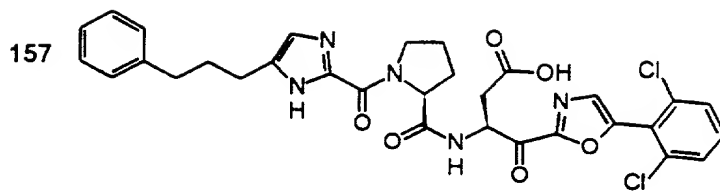


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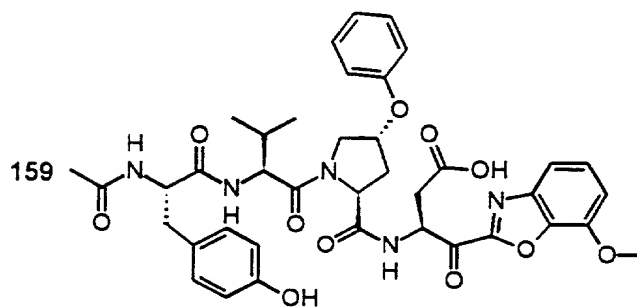
0988673-06404

5

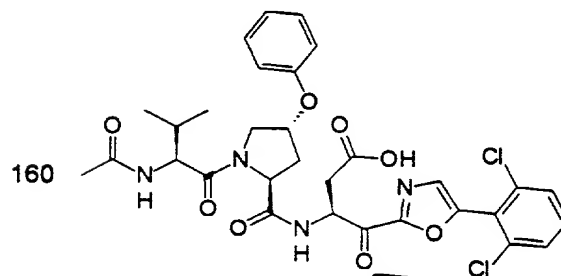
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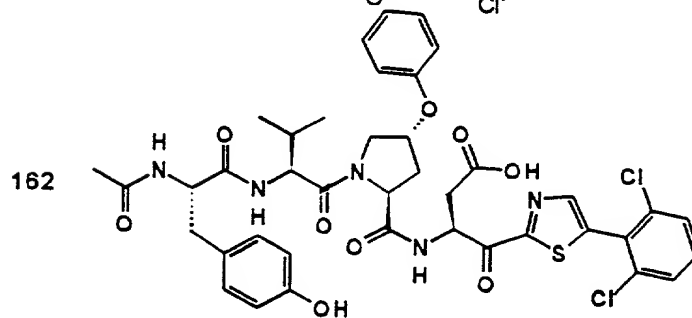
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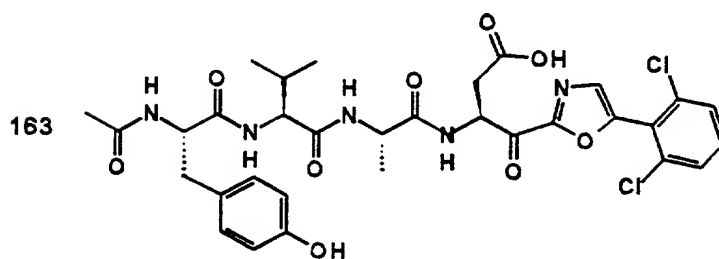
;



;



; and



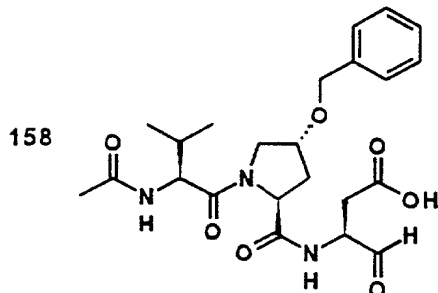
.

09806773-052404

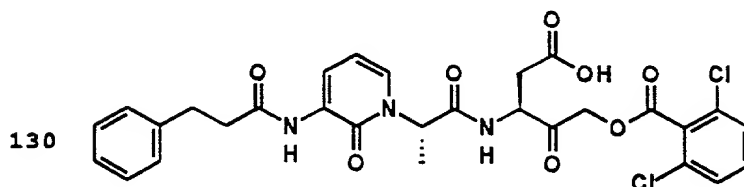
5

10

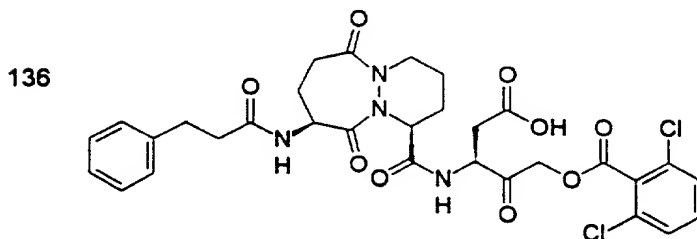
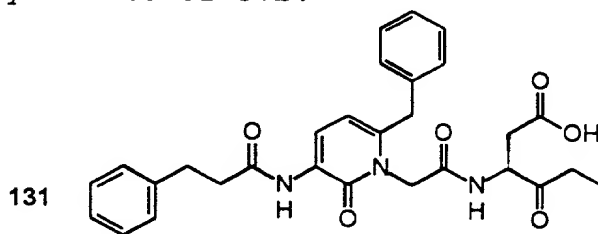
Compound 158 was synthesized by a method similar to the method used in the synthesis of (K).

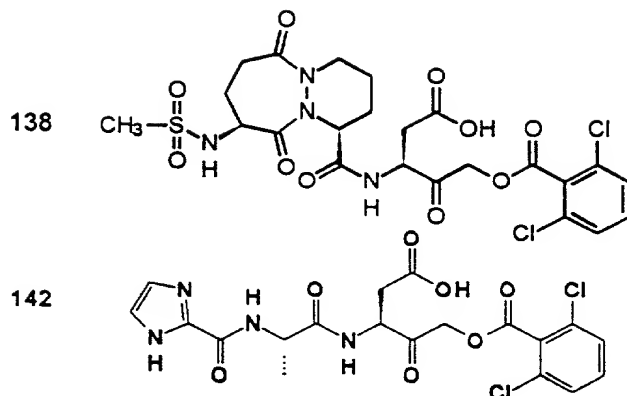


Compound 130 was synthesized by a method similar to the method used in the synthesis of 56b.



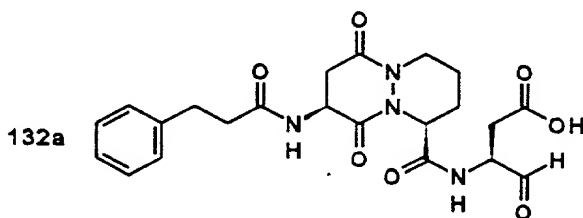
5 Compounds 131, 136, 138, and 142 were synthesized by a method similar to the method used in the synthesis of 57b.



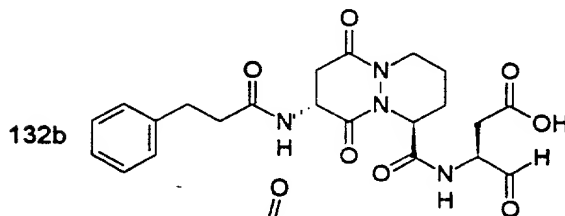


; and

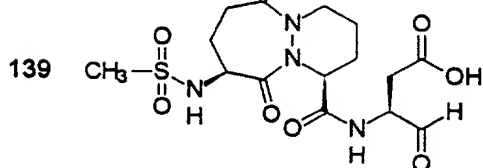
Compounds 132a, 132b, 139, 140, and 141 were synthesized by a method similar to the method used in the synthesis of 47a. The starting material for compound 140 was obtained as described in: Robl, et al., J. Am. Chem. Soc., 116, pp. 2348-2355 (1994). The starting material for compound 141 was obtained as described in: Wyvratt, et al., Pept. Struct. Funct. Proc. (8th Am. Pept. Symp.), (1983) or USP 4415496.



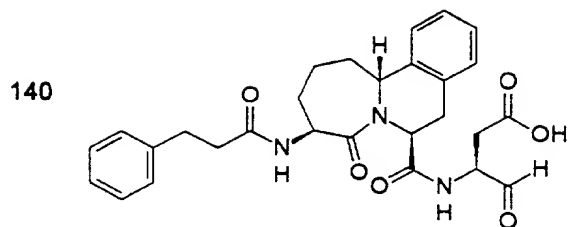
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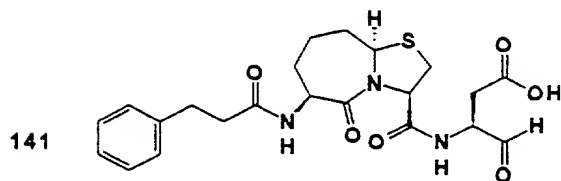
;



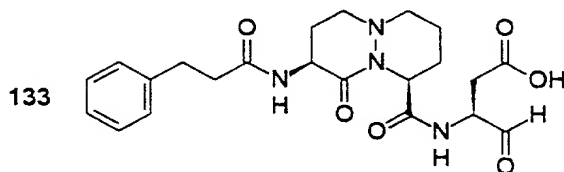
;



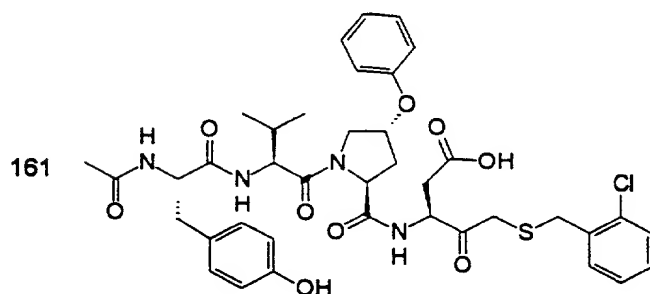
; and



5 Compound 133 was synthesized by a method similar to the method used in the synthesis of 47b.



Compound 161 was synthesized by a method similar to the method used in the synthesis of 125a.

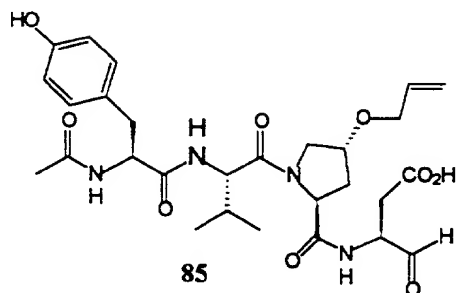


10

Compounds 22e, 54b, 54j, 54k, and 57b were synthesized as described in example 5.



Compounds 85, 86, 87, 88, 89, 90, 91, 92, 98, 102a, 102b, 102c, 106a, 106b, 106c, 108a, 108b, 108c, 114a, 114b, 115, 121, 125a, and 125b were synthesized as follows.



5     **N-(N-Acetyl-tyrosinyl-valinyl-(4(R)-allyloxy prolinyl))-3(S)-amino-4-oxobutanoic acid (85).**

Step A.     **N-tert-Butoxycarbonyl-4(R)-**

**allyloxyproline.** N-tert-Butoxycarbonyl(4R)-

hydroxyproline (9.25 g, 40 mmol) was added to a

10     solution of 60% sodium hydride (3.36 g, 84 mmol) in 100 ml of anhydrous tetrahydrofuran and stirred for 2 hours at room temperature. Allyl bromide (6.9 ml, 80 mmol) was added to the mixture and refluxed for 6

15     hours. The mixture was quenched with the addition of ice chips, then additional water was added and the mixture was washed with hexane. The aqueous layer

20     was acidified with 10% sodium hydrogen sulfate and extracted with ethyl acetate (2 x 150 ml). The combined extracts were dried over anhydrous sodium sulfate, filtered and evaporated to give 5 g of the title product with no further purification.

25     <sup>1</sup>H NMR (CDCl<sub>3</sub>; exist as rotamers) δ 5.92-5.82 (1H, m), 5.3-5.14 (2H, m) 4.5-4.31 (1H, m), 4.16-4.05 (1H, m), 4.04-3.9 (1H, m), 3.79-3.5 (3H, m), 2.43-2.2 (1.5H, m), 2.15-2.10 (0.5H, m), 1.45 (4.5H, s), 1.35 (4.5H, s).

Step B. **4(R)-Allyloxyproline methyl ester**

**hydrochloride.** N-tert-Butoxycarbonyl-4(R) -

allyloxyproline (5 g, 18.4 mmol) was refluxed in 50 ml of saturated methanolic hydrogen chloride for 6

hours. The mixture was evaporated in vacuo to give 3.78 g of a yellow gum as the title compound: <sup>1</sup>H NMR

(CDCl<sub>3</sub>) δ 5.83-5.72 (1H, m), 5.24-5.14 (1H, d), 5.13-5.08 (1H, d), 4.55-4.3 (3H, m), 4.25-4.15 (1H, m),

3.9 (1.5H, s), 3.78 (1.5H, s), 3.7-3.28 (3H, m),

2.45-2.32 (1H, m), 2.2-2.05 (1H, m).

Step C. **N-Acetyl-tyrosinyl-valinyl-(4(R) -**

**allyloxyproline) methyl ester.** 4(R)-Allyloxyproline methyl ester hydrochloride (1.05 g, 4.75 mmol) and N-acetyl-Tyr-Val-OH (1.68 g, 5.21 mmol) were dissolved in 10 ml of a 1:1 mixture of dichloromethane and dimethylformamide and cooled to 0 °C.

Diisopropylethylamine (1 ml, 5.93 mmol) was added to the cooled mixture followed by the addition of N-hydroxybenzotriazole (0.769 g, 5.69 mmol) and 1-(3-Dimethylaminopropyl)-3-ethylcarbodiimide

hydrochloride (1.18 g, 6.2 mmol). After stirring for 2 hours, the mixture was warmed to room temperature and stirred for 16 hours. The reaction was poured into 150 ml of ethyl acetate and washed with 50ml

each of water, 10% sodium hydrogen sulfate, and 10% sodium bicarbonate. The organic layer was dried over sodium sulfate, filtered, and evaporated to give a light yellow solid. This was purified by flash chromatography eluting with

dichloromethane/methanol/pyridine (100:3:0.5) to give 780 mg of the title compound. <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 7.02-6.96 (2H, d), 6.67-6.63 (2H, d), 5.95-5.85 (1H, m),

5.34-5.27 (1H, d), 5.16-5.13 (1H, d), 4.53-4.38 (3H, m), 4.28-4.22 (1H, m), 4.12-3.97 (3H, m), 3.82-3.73 (1H, m), 3.72 (3H, s), 3.04-2.88 (2H, m), 2.85-2.72 (2H, m), 2.45-2.34 (1H, m), 2.08-1.95 (2H, m), 1.92 (3H, s), 1.00-0.92 (6H, 2 x d).

Step D. **N-(N-Acetyl-tyrosinyl-valinyl-(4(R)-allyloxyprolinyl))-3(S)-amino-4-oxobutanoic acid**

**tert-butyl ester semicarbazone.** N-Acetyl-tyrosinyl-valinyl-(4-allyloxyproline) methyl ester (770 mg,

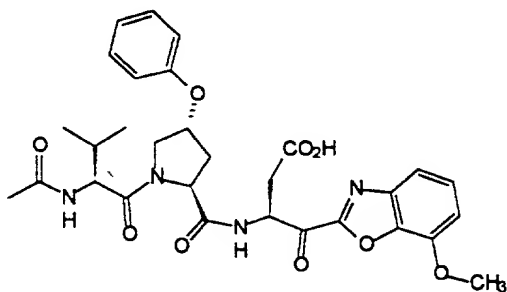
10 1.57 mmol) was dissolved in 20 ml of tetrahydrofuran and 4 ml of methanol. Lithium hydroxide (145 mg, 3.46 mmol) was added to the mixture and stirred at room temperature. After two hours, 1 ml of 10% hydrogen chloride was added and the mixture  
15 evaporated in vacuo to give a solid residue then partitioned between 5ml of water and 50 ml of ethyl acetate and the organic layer separated and evaporated in vacuo to give 430 mg of the acid that was used immediately in the next step.

20 N-Acetyl-tyrosinyl-valinyl-4-allyloxyproline (420 mg, 0.88 mmol) and 3-amino-4-oxobutyric acid tert-butyl ester semicarbazone (184 mg, 0.8 mol, Graybill et al., Int. J. Protein Res., 44, pp. 173-82 (1994)) to give 100 mg (20%) of the title compound as a white  
25 amorphous solid: <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 7.24-7.2 (1H, m), 7.04-6.97 (2H, d), 6.73-6.65 (2H, d), 5.98-5.86 (1H, m), 5.35-5.24 (1H, d), 5.17-5.12 (1H, m), 4.12-3.98 (2H, m), 3.72-3.67 (1H, m), 2.98-2.92 (3H, m), 2.38-2.32 (1H, m), 2.1-2.02 (2H, m), 1.92 (3H, s), 0.98-0.89 (6H, 2 x d).  
30

Step E. N-(N-Acetyl-tyrosinyl-valinyl-(4(R)-allyloxyprolinyl))-3(S)-amino-4-oxobutanoic acid (85). N-(N-Acetyl-tyrosinyl-valinyl-(4(R)-allyloxyprolinyl))-3(S)-amino-4-oxobutanoic acid

5 tert-butyl ester semicarbazone (100 mg) was deprotected as described (Example 3, compound K, Step C) to give 44.2 mg (53%) of the title compound: <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 7.04-6.97 (2H, d), 6.72-6.65 (2H, d), 5.97-5.86 (1H, m), 5.32-5.25 (1H, d), 5.17-5.12 (1H, d), 4.62-4.40 (3H, m), 4.30-4.13 (2H, m), 4.12-3.96 (3H, m), 3.75-3.68 (1H, m), 2.99-2.92 (1H, m), 2.78-2.70 (1H, m), 2.70-2.48 (2H, m), 2.35-2.30 (1H, m), 2.17-1.95 (2H, m), 1.92 (3H, s), 0.98-0.88 (6H, 2 x d).

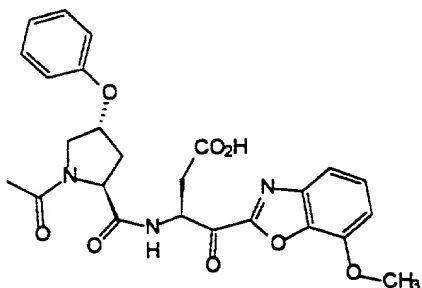
15 Compounds 86 and 87 were prepared by a similar method described for the synthesis of 69a in example 5:



86

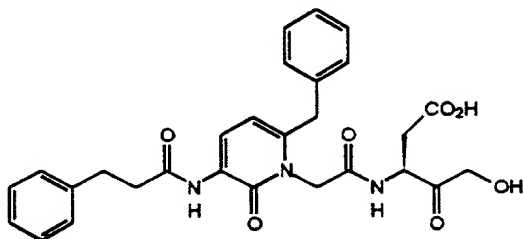
20 N-Acetyl-(S)-valinyl-(4-(S)-phenoxy)prolinyl-3(S)-amino-4-(7-methoxybenzoxazol-2-yl)-4-oxo-butanoic acid (86). N-Acetyl-(S)-valinyl-(S)-(4-(S)-phenoxy)proline was converted to 86 as a white powder: <sup>1</sup>H NMR (DMSO-d<sub>6</sub>) δ 8.75(d, 1H), 7.6-7.2(m, 4H), 7.0-6.8(m, 4H), 5.5(m, 1H), 5.05(s, 1H), 4.5(t,

1H), 4.29(t, 1H), 4.0(s, 3H), 4.0-3.8(m, 2H), 3.0-2.8(dd, 2H), 2.3(m, 1H), 2.09(m, 1H), 1.95-1.8(m, 2H), 1.78(s, 3H), 1-0.7(dd, 6H).



87

**N-Acetyl(4-(R)-phenoxy)prolinyl-3(S)-amino-4-(7-methoxybenzoxazol-2-yl)-4-oxo-butanoic acid (87):** N-Acetyl-(S)-(4-(S)-phenoxy)proline was converted to 87 as a white powder: <sup>1</sup>H NMR (DMSO-d<sub>6</sub>) δ 9.1(d, 1H), 8.76(d, 1H), 7.6-7.2(m, 4H), 7.0-6.9(m, 4H), 5.55(m, 1H), 5.45(m, 1H), 5.0(m, 2H), 4.56(t, 1H), 4.40(t, 1H), 4.0(s, 3H), 3.9(dd, 1H), 3.76(d, 1H), 3.64(d, 1H), 3.1-2.9(m, 1H), 2.8(m, 1H), 2.50(m, 1H), 2.3-2.2(m, 1H), 2.09(m, 1H), 1.95 and 1.75(2 x s, 3H, rotamers)



88

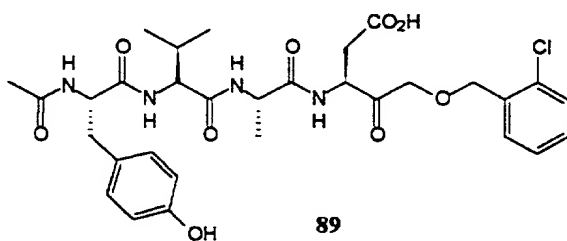
**N-2-(6-Benzyl-1,2-dihydro-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl) acetyl-3(S)-amino-5-hydroxy-4-oxo-pentanoic acid (88).** N-2-(6-Benzyl-

1,2-dihydro-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl) acetyl-3(S)-amino-5-hydroxy-4-oxo-pentanoic acid tert-butyl ester was prepared from **52b** and **81** following the method described for the synthesis of

**83a** to give a white solid (45%):  $^1\text{H NMR}(\text{CDCl}_3)$   $\delta$  8.40(d, 1H), 8.20(s, 1H), 7.4-7.1(m, 11H), 6.18(s, 1H), 4.72(m, 1H), 4.65-4.5(q, 2H), 4.4-4.2(dd, 2H), 4.0(s, 2H), 3.04(t, 2H), 2.9(dd, 1H), 2.76(t, 2H), 2.55(dd, 1H), 1.39(s, 9H).

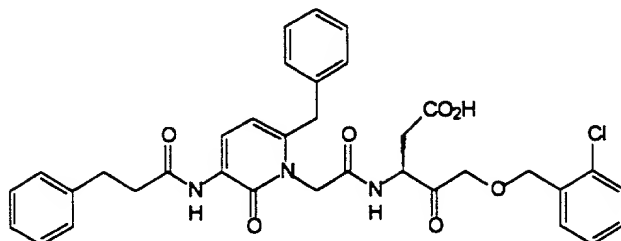
The resulting product was converted to **88** by method described in example 5, compound **84a** to give the title compound (42%) as a white solid:  $^1\text{H NMR}(\text{CDCl}_3)$   $\delta$  8.5(d, 1H), 8.1(d, 1H), 8.0(m, 1H), 7.4-7.1(m, 11H), 6.3(d, 1H), 4.9-4.8(m, 2H), 4.6-4.4(m, 2H), 4.3(dd, 1H), 4.1(s, 2H), 3.3(t, 1H), 3.05(t, 2H), 2.8-2.6(m, 3H)

Compounds **89** and **90** were prepared by a similar method described for the preparation of **84a** in example 5.



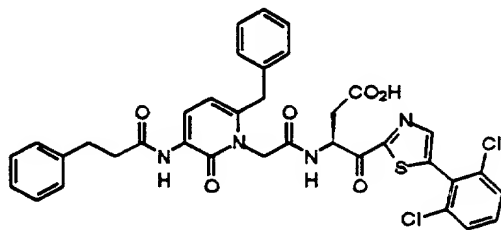
**N-Acetyl-(S)-tyrosinyl-(S)-valinyl-(S)-alaninyl-3(S)-amino-5-(2-chlorobenzyloxy)-4-oxo-pentanoic acid (89)** was prepared from Ac-Tyr-Val-Ala-OH and (3S) t-butyl N-(allyloxycarbonyl)-3-amino-5-(2-chlorophenyl-methoxyl)-4-oxo-pentanoate (prepared by a similar method as **82**) to give a white solid:  $^1\text{H NMR}$  (DMSO-

d<sub>6</sub>) δ 9.15(s, 1H), 8.5(d, 1H), 7.98(d, 1H), 7.75(d, 1H), 7.55-7.3(m, 4H), 7.0(d, 1H), 6.6(d, 2H), 4.6-4.3(m, 6H), 4.3-4.1(m, 2H), 2.9(d, 1H), 2.76(dd, 1H), 2.7-2.5(m, 2H), 1.95(m, 1H), 1.75(s, 3H), 1.2(d, 3H), 0.9-0.7(dd, 6H)



90

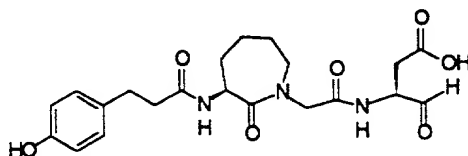
N-2-(6-Benzyl-1,2-dihydro-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl) acetyl-3-amino-5-(2-chlorobenzyloxy)-4-oxo-pentanoic acid (90) was prepared from 52b and (3S) t-butyl N-(allyloxycarbonyl)-3-amino-5-(2-chlorophenyl-methoxyl)-4-oxo-pentanoate (prepared by a similar method as 82) to give a white solid: <sup>1</sup>H NMR(DMSO-d<sub>6</sub>) δ 9.2(s, 1H), 8.75(d, 1H), 7.7-7.1(m, 14H), 6.4(d, 1H), 4.65(d, 6H), 4.56(s, 1H), 4.6-4.35(dd, 1H), 3.9(s, 2H), 2.9-2.6(m, 6H)



91

N-2-(6-Benzyl-1,2-dihydro-2-oxo-3-(3-phenylpropionyl)amino-1-pyridyl) acetyl-3(S)-amino-5-(5-(2,6-dichlorophenyl)thiazol-2-yl)-4-oxo-pentanoic

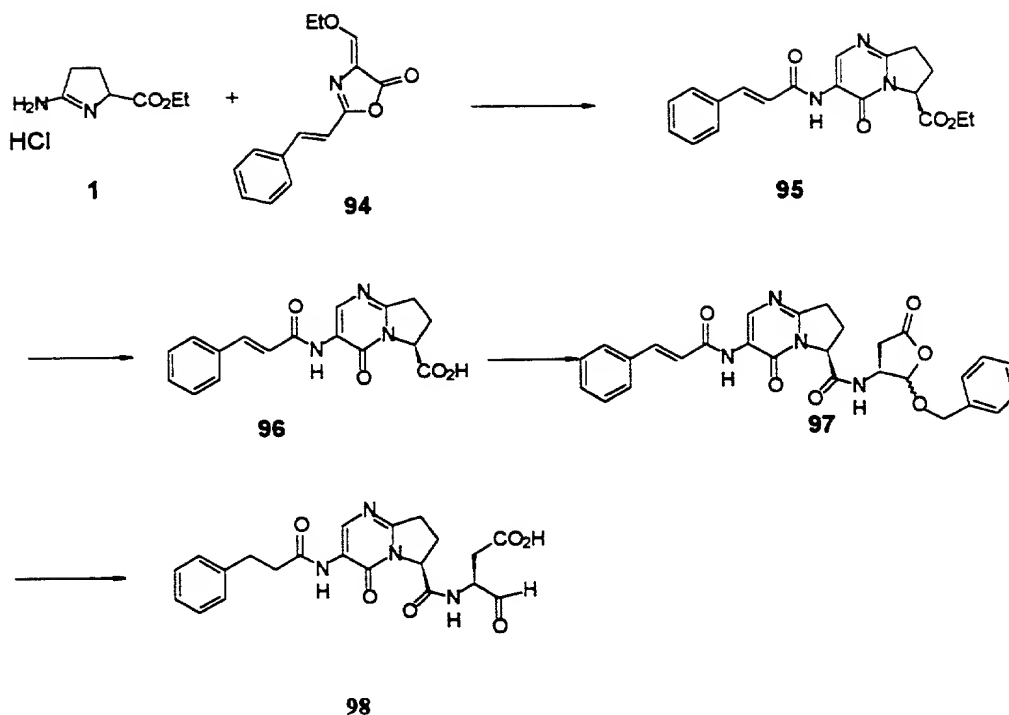
acid (91) was prepared from 52b and 3-(Allyloxycarbonyl)-amino-4-[(2,6-dichloro-phenyl)-thiazol-2-yl]-4-hydroxy-butyric acid tert-butyl ester (99) as described for the preparation of 69a to give an off-white powder:  $^1\text{H}$  NMR(DMSO- $d_6$ )  $\delta$  9.32(s, 1H), 9.05(d, 1H), 8.27(d, 1H), 8.18(d, 1H), 7.7(d, 1H), 7.6(t, 1H), 7.4-7.1(m 11H), 6.1(d, 1H), 5.64(m, 1H), 4.8-4.6(dd, 2H), 3.85(s, 2H), 3.02(m, 1H), 2.9-2.7(m, 4H).



92

3-(S)-(2-(3[3-(S)-(4-Hydroxy-phenyl)-propionylamino]-2-oxo-azepan-1-yl)-acetyl-amino)-4-oxo-butyric acid (92) was prepared from 2-(3[3-(S)-(4-Hydroxy-phenyl)-propionylamino]-2-oxo-azepan-1-yl)-acetic acid and N-allyloxycarbonyl-4-amino-5-benzyloxy-2-oxotetrahydrofuran (Chapman, Biorg. Med. Chem. Lett., 2, pp. 613-18 (1992)) by a similar method described for the synthesis of 54a to give the title compound as a white solid:  $^1\text{H}$  NMR(DMSO- $d_6$ )  $\delta$  9.10-9.20(s, 1H), 8.40(s, 1H), 7.88(d, 1H), 7.0(d, 2H), 6.64(d, 2H), 4.60(t, 1H), 4.10(q, 2H), 3.9-4.2(m, 2H), 3.6(m, 1H), 3.18(d, 2H), 2.70(t, 2H), 2.40(m, 2H), 1.85-1.40(m, 8H).





4-Ethoxymethylene-2-styryl-4H-oxazol-5-one (94) was prepared according to Cornforth, The Chemistry of Penicillin, Clarke, Johnson, Robinson, (eds.) Princeton University Press, p. 804 (1949)

4-Oxo-3-(3-phenyl-acryloylamino)-4,6,7,8-tetrahydropyrrolo[1,2-a]pyrimidine-(6S)-carboxylic acid ethyl ester (95) was prepared from 94 by the procedure in example 5 for compound 3 to give 4.5g (30%) of the title compound:  $^1\text{H}$  NMR ( $\text{CD}_3\text{OD}$ )  $\delta$  1.3 (t, 3H), 2.35 (m, 1H), 2.65 (m, 1H), 3.1 (m, 1H), 3.15 (m, 1H), 4.25 (q, 2H), 5.15 (dd, 1H), 6.95 (d, 1H), 7.4 (m, 3H), 7.6 (m, 2H), 7.65 (d, 1H), 8.95 (s, 1H).

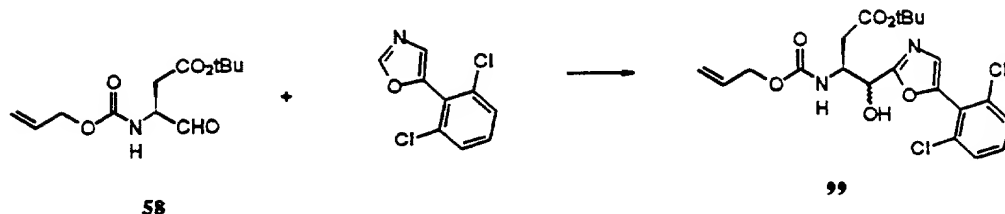
4-Oxo-3-(3-phenyl-acryloylamino)-4,6,7,8-tetrahydro-pyrrolo[1,2-a]pyrimidine-(6S)-carboxylic acid (96) A mixture of 4-Oxo-3-(3-phenyl-acryloylamino)-4,6,7,8-tetrahydro-pyrrolo[1,2-a]pyrimidine-(6S)-carboxylic acid ethyl ester (95, 3.1g, 8.8mmol) and aqueous 1N lithium hydroxide (8.8mL, 8.8mmol) in methanol (10mL) was stirred 18h at room temperature. The reaction was diluted with water and washed with ethyl ether (1 x 20mL). The aqueous layer was acidified with conc. hydrochloric acid. The solid was collected by filtration and washed with water. The solid was dried in a vacuum oven at 50 °C for 18h to give 2.2g (75%) of the title compound as a tan solid: <sup>1</sup>H NMR(CD<sub>3</sub>OD) δ 2.4(m, 1H), 2.7(m, 1H), 3.1(m, 1H), 3.2(m, 1H), 5.15(dd, 1H), 7.0(d, 1H), 7.4(m, 3H), 7.6(m, 2H), 7.65(d, 1H), 8.95(s, 1H)

4-Oxo-3-(3-phenyl-acryloylamino)-4,6,7,8-tetrahydro-pyrrolo[1,2-a]pyrimidine-(6S)-carboxylic acid (2-benzyloxy-5-oxo-tetrahydro-furan-(3S)-yl)-amide (97) was prepared from 96 by the method described in example 3 for compound H, step A to give 0.52g (75%) of the title compound as a mixture of diastereomers: <sup>1</sup>H NMR(CDCl<sub>3</sub>) δ 2.3-2.7(m, 3H), 2.9(dd, 1H), 3.05(m, 1H), 3.3(m, 1H), 4.4-4.8(m, 2H), 4.9(2 x d, 1H), 5.05(m, 1H), 5.55(2 x s, 1H), 6.6(2 x d, 1H), 7.4(m, 6H), 7.55(m, 4H), 7.65(2 x d, 1H), 8.0(m, 2H), 9.2(s x 2, 1H).

4-Oxo-(3S)-{[4-oxo-3-(3-phenyl-propionylamino)-4,6,7,8-tetrahydro-pyrrolo[1,2-a]pyrimidine-(6S)-carbonyl]-amino}-butyric acid (98) was prepared by the procedure in example 3 for compound H, step D to

give 0.13g (45%) of the title compound:  $^1\text{H}$

NMR( $\text{CD}_3\text{OD}$ )  $\delta$  2.35(m, 1H), 2.45-2.75(m, 3H), 2.8(t, 2H), 3.0(t, 2H), 3.1(m, 1H), 3.25(m, 1H), 4.3(m, 1H), 6.65(dd, 1H), 5.15(m, 1H), 7.15(m, 1H), 7.3(m, 4H), 8.8(a, 1H).



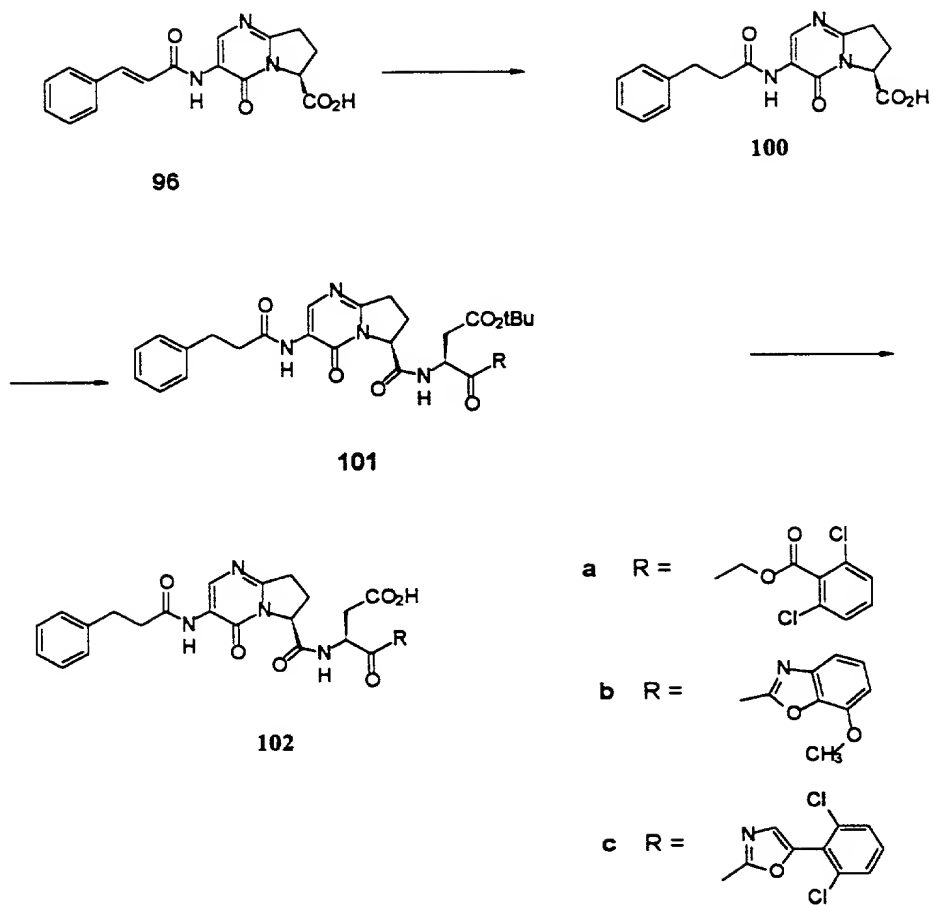
3(S)-(Allyloxycarbonyl)-amino-4-[(2,6-dichlorophenyl)-oxazol-2-yl]-4(R,S)-hydroxy-butyric acid tert-butyl ester (99). A solution of 5-(2,6-Dichlorophenyl)oxazole (2.71g, 12.7mmol; prepared by a similar method described in Tet. Lett. 23, p2369 (1972)) in tetrahydrofuran (65mL) was cooled to -78 °C under a nitrogen atmosphere. To this solution was added n-butyl lithium (1.5M solution in hexanes, 8.5mL, 13.3mmol) and stirred at -78 °C for 30min. Magnesium bromide etherate (3.6g, 13.9mmol) was added and the solution was allowed to warm to -45 °C for 15min. The reaction was cooled to -78 °C and aldehyde 58 (3.26g, 12.7mmol; Graybill et al., Int. J. Protein Res., 44, pp. 173-182 (1993)) in tetrahydrofuran (65mL) was added dropwise. The reaction was stirred for 25min., then allowed to warm to -40 °C and stirred for 3h, and then at room temperature for 1h. The reaction was quenched with 5%  $\text{NaHCO}_3$  (12mL) and stirred for 3h. The tetrahydrofuran was removed in vacuo and the resulting residue was extracted with dichloromethane. The organic layer was washed with saturated sodium chloride solution and dried over magnesium sulfate,

filtered, and concentrated to yield 6.14g of the title compound. Purification gave 4.79g (80%) of

5 99:  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  1.45(s, 9H), 2.7-2.5(m, 2H), 2.8(dd, 1H), 4.2, 4.4(2 x d, 1H), 4.7-4.5(m, 3H), 5.35-5.1(m, 2H), 5.6, 5.7(2 x d, 1H), 6.0-5.8(m, 1H), 7.2(d, 1H), 7.3(m, 1H), 7.4(m, 2H).

**4-Oxo-3-(3-phenyl-propionylamino)-4,6,7,8-tetrahydro-pyrrolo [1,2-a]pyrimidine-(6S)-carboxylic acid (100).**

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T07290-229850  
10 A mixture of 4-Oxo-3-(3-phenyl-acryloylamino)-4,6,7,8-tetrahydro-pyrrolo[1,2-a]pyrimidine-(6S)-carboxylic acid (96; 2.1g, 6.5mmol) and 20% palladium hydroxide on carbon (0.5g) in methanol (50mL) was stirred under a hydrogen atmosphere for 4h. The resulting mixture was filtered and concentrated to  
15 yield 2.1g (100%) of the title compound as a white solid:  $^1\text{H}$  NMR( $\text{CD}_3\text{OD}$ )  $\delta$  2.35(m, 1H), 2.65(m, 1H), 2.75(t, 2H), 3.0(t, 2H), 3.1(m, 1H), 3.15(m, 1H), 5.1(dd, 1H), 7.15(m, 1H), 7.25(m, 4H), 8.75(s, 1H)



2,6-Dichloro-benzoic acid 4-tert-butoxycarbonyl-2-oxo-(3S)-{[4-oxo-3-(3-phenyl-propionylamino)-4,6,7,8-tetrahydro-pyrrolo[1,2-a]pyrimidine-(6S)-carbonyl]-amino}-butyl ester (101a) was prepared by the procedure in example 5 for compound 56a to give 0.16g (20%) of the title compound:  $^1\text{H}$  NMR( $\text{CD}_3\text{OD}$ )  $\delta$  1.45(s, 9H), 2.3(m, 1H), 2.6(m, 1H), 2.7(m, 3H), 2.95(m, 3H), 4.8(m, 1H), 5.1(m, 1H), 5.2(q, 2H), 7.1(m, 1H), 7.2(m, 4H), 7.4(m, 3H), 8.75(s, 1H).

4-(7-methoxy-benzoxazol-2-yl)-4-oxo-(3S)-{[4-oxo-3-(3-phenyl-propionylamino)-4,6,7,8-tetrahydro-pyrrolo[1,2-a]pyrimidine-(6S)-carbonyl]-amino}-butric

acid tert-butyl ester (101b). 4-Hydroxy-4-(7-methoxy-benzoxazol-2-yl)-(3S)-{[4-oxo-3-(3-phenyl-propionylamino)-4,6,7,8-tetrahydro-pyrrolo[1,2-a]pyrimidine-(6S)-carbonyl]-amino}-butyric acid tert-butyl ester was prepared from 100 and 66a by the procedure in example 5 for compound 67a to give 0.95g (quantitative) of the product as a mixture of diastereomers: <sup>1</sup>H NMR(CD<sub>3</sub>OD) δ 1.45(2 x s, 9H), 2.2(2 x m, 1H), 2.35-3.0(m, 9H), 4.0(m, 3H), 4.75(m, 1H), 4.85(m, 1H), 5.05(2 x dd, 1H), 7.1(2 x dd, 1H), 7.15-7.3(m, 4H), 7.5(2 x t, 1H), 7.8(2 x d, 1H), 8.55(2 x dd, 1H), 8.7(2 x s, 1H).

The resulting product was converted to 101b by the procedure in example 5 for compound 68a to give

0.36g (50%) of the title compound: <sup>1</sup>H NMR(CD<sub>3</sub>OD) δ 1.4(s, 9H), 2.35(m, 1H), 2.55(m, 1H), 2.75(t, 2H), 2.95(t, 2H), 3.00(m, 1H), 3.1(dd, 2H), 3.15(m, 1H), 5.15(dd, 1H), 5.65(t, 1H), 7.1(m, 2H), 7.2(m, 4H), 7.4(m, 2H), 8.7(s, 1H)

4-[5-(2,6-Dichloro-phenyl)-oxazol-2-yl]-4-oxo-(3S)-{[4-oxo-3-(3-phenyl-propionylamino)-4,6,7,8-tetrahydro-pyrrolo[1,2-a]pyrimidine-(6S)-carbonyl]-amino}-butyric acid tert-butyl ester (101c). 4-[5-(2,6-Dichloro-phenyl)-oxazol-2-yl]-4-hydroxy-(3S)-{[4-oxo-3-(3-phenyl-propionylamino)-4,6,7,8-tetrahydro-pyrrolo[1,2-a]pyrimidine-(6S)-carbonyl]-amino}-butyric acid tert-butyl ester from 100 and 99 using the method described in example 5, compound 67a to give 0.09g (60%) of the product as a mixture of diastereomers: <sup>1</sup>H NMR(CD<sub>3</sub>OD) δ 1.45(2 x s, 9H), 2.2(m, 1H), 2.5(m, 2H), 2.7(2 x dd, 1H), 2.75(t, 2H),

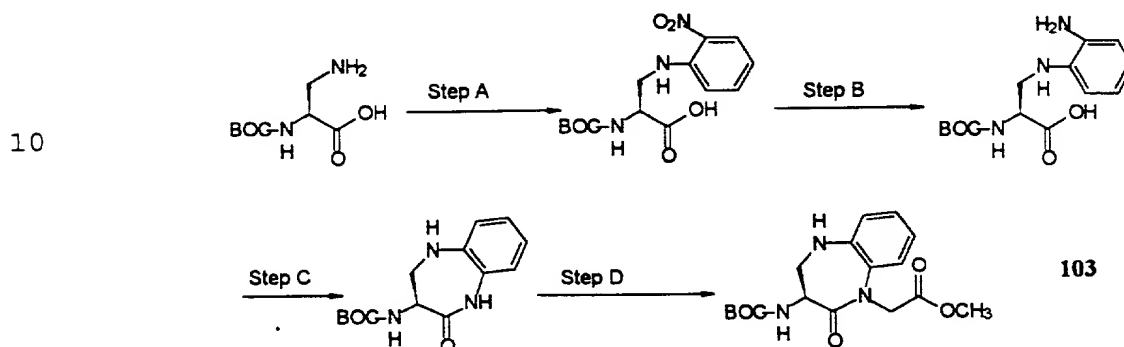
2.9-3.1(m, 4H), 4.7(m, 1H), 5.1(m, 2H), 7.1(m, 1H),  
7.1-7.25(m, 4H), 7.4(t, 1H), 7.5(t, 1H), 8.55(d, 1H),  
8.75(s, 1H).

5 The resulting product was converted to 101c by the  
method described in example 5, compound 68a to give  
0.04g (45%) of the title compound: <sup>1</sup>H NMR(CD<sub>3</sub>OD) δ  
1.4(s, 9H), 2.3(m, 1H), 2.6(m, 1H), 2.75(t, 2H),  
2.95(t, 2H), 2.9-3.2(m, 4H), 5.2(dd, 1H), 5.55(t,  
1H), 7.1(m, 1H), 7.25(m, 4H), 7.55(m, 3H), 8.75(s,  
10 1H).

2,6-Dichloro-benzoic acid 4-carboxy-2-oxo-(3S)-{[4-  
oxo-3-(3-phenyl-propionylamino)-4,6,7,8-tetrahydro-  
pyrrolo[1,2-a]pyrimidine-(6S)-carbonyl]-amino}-butyl  
ester (102a) was prepared from 101a by the procedure  
15 in example 5 for compound 57a to give 0.12g (80%) of  
the title compound: <sup>1</sup>H NMR(CD<sub>3</sub>OD) δ 2.35(m, 1H),  
2.65(m, 1H), 2.75(m, 2H), 2.85(dd, 1H), 2.95(m, 2H),  
3.0(dd, 1H), 3.15(m, 1H), 3.25(m, 1H), 4.55(dd, 1H),  
5.15(m, 1H), 5.25(q, 2H), 7.15(m, 1H), 7.25(m, 4H),  
20 7.45(m, 1H), 8.8(s, 1H).

4-(7-methoxy-benzoxazol-2-yl)-4-oxo-(3S)-{[4-oxo-3-(3-  
phenyl-propionylamino)-4,6,7,8-tetrahydro-pyrrolo [1,2-  
a]pyrimidine-(6S)-carbonyl]-amino}-butric acid (102b) was  
prepared from 101b by the procedure described in example 5  
25 for compound 69a to give 0.12g (35%) of the title  
compound: <sup>1</sup>H NMR(DMSO-d<sub>6</sub>) δ 2.1(m, 1H), 2.55(m, 1H), 2.7-  
3.1(m, 8H), 4.05(s, 3H), 5.1(dd, 1H), 5.55(t, 1H), 7.2(m,  
1H), 7.25(m, 5H), 7.5(t, 1H), 7.55(d, 1H), 8.7(s, 1H),  
9.2(d, 1H), 9.4(s, 1H), 12.7(br, 1H).

4-[5-(2,6-Dichloro-phenyl)-oxazol-2-yl]-4-oxo-(3S)-  
 {[4-oxo-3-(3-phenyl-propionylamino)-4,6,7,8-  
 tetrahydro-pyrrolo[1,2-a] pyrimidine-(6S)-carbonyl]-  
 amino}-butyric acid (102c) was prepared from 101c as  
 5 described in example 5 for compound 69a to give 0.01g  
 (40%) of the title compound: <sup>1</sup>H NMR(CD<sub>3</sub>OD) δ 2.35(m,  
 1H), 2.6(m, 1H), 2.75(t, 2H), 2.95(t, 2H), 3.05(m,  
 1H), 3.15(m, 3H), 5.15(dd, 1H), 5.55(t, 1H), 7.15(m,  
 1H), 7.2(m, 4H), 7.55(m, 3H), 8.8(s, 1H)



(3-tert-Butoxycarbonylamino-2-oxo-2,3,4,5-tetrahydro-  
 benzo[b][1,4]diazepin-1-yl)acetic acid methyl ester  
 (103).

15 **Step A. 2(S)-tert-Butoxycarbonylamino-3-(2-nitrophenyl-amino)-propionic acid.** 2-tert-  
 Butoxycarbonylamino-3-aminopropionic acid (10 g, 49  
 mmol), 2-fluoronitrobenzene (5.7 ml, 54 mmol), and  
 sodium bicarbonate (8.25 g, 98 mmol) was taken into  
 130 ml of dimethylformamide and heated at 80 °C for  
 20 18 hours. The reaction was evaporated in vacuo to  
 give a viscous orange residue that was dissolved in  
 300 ml of water and extracted with diethyl ether (3 x  
 150 ml). The aqueous solution was acidified to pH 5  
 with 10 % sodium hydrogen sulfate and extracted with



ethyl acetate (3 x 250 ml). The combined extracts were dried over anhydrous sodium sulfate, filtered, and evaporated to give 12.64 g (83 %) of the title compound as an orange amorphous solid. <sup>1</sup>H NMR (CD<sub>3</sub>OD)

5    δ 8.15-8.10 (1H,d), 7.54-7.48 (1H,t), 7.13-7.08 (1H, d), 6.73-6.65 (1H, t), 4.45-4.35 (1H, m), 3.9-3.8 (1H, dd), 3.65-3.55 (1H, dd), 1.45 (9H, s).

**Step B. 2(S)-tert-Butoxycarbonylamino-3-(2-aminophenyl-amino)-propionic acid.** A mixture of 2-

10    tert-Butoxycarbonylamino-3-(2-nitrophenylamino)propionic acid (12.65 g, 40.5 mmol) and 0.5 g of 10% Pd/C in 100 ml of methanol under hydrogen at 1 atmosphere was stirred for 4 hrs. The solution was filtered through Celite 545 and the

15    filtrate evaporated in vacuo to afford 11.95 g of the title compound in quantitative yield as a dark brown solid that was used without purification. <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 6.75-6.70 (3H,m), 6.65-6.58 (1H, m), 4.35-4.3 1H, m), 3.6-3.38 (2H, m), 1.45 (9H, s).

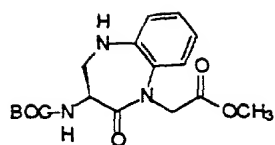
**Step C. 3(S)-tert-Butoxycarbonylamino-1,3,4,5-tetrahydro-benzo[b][1,4] diazepin-2-one.** 1-(3-Dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride (8.54 g, 44.5 mmol) was added to a cooled (0 °C) solution of 2-tert-butoxycarbonylamino-3-(2-

25    aminophenylamino)propionic acid (11.95 g, 40.5 mmol) in 100 ml of dimethylformamide and stirred for 18 hours. The reaction was poured into 700 ml of ethyl acetate and washed four times with 100 ml of water. The organic layer was dried over anhydrous sodium

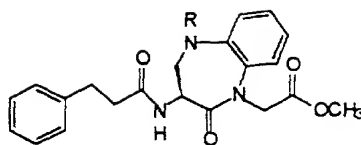
30    sulfate, filtered, and evaporated to give a brown solid that was purified by flash chromatography

eluting with 3:7 ethyl acetate/hexane to give 8 g  
(71%) of the title compound:  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  7.78 (1H, s), 7.02-6.95 (1H, m), 6.88-6.82 (1H, m), 6.82-6.78 (1H, m), 6.75-6.70 (1H, m), 5.8-5.7 (1H, d), 4.55-4.45 (1H, m), 3.95 (1H, s), 3.9-3.82 (1H, m), 3.48-3.40 (1H, m), 1.45 (9H, s).

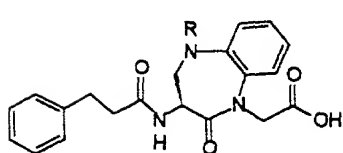
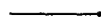
**Step D. (3(S)-tert-Butoxycarbonylamino-2-oxo-2,3,4,5-tetrahydrobenzo[b][1,4]diazepin-1-yl)acetic acid methyl ester (103).** A 1.0 M solution of lithium bis(trimethylsilyl)amide (3.4 ml, 3.4 mmol) in THF was added dropwise to a -78 °C solution of 3-tert-butoxycarbonylamino-1,3,4,5-tetrahydrobenzo[b][1,4]diazepin-2-one (0.94 g, 3.38 mmol) in 20 ml of anhydrous tetrahydrofuran and stirred for 30 minutes. Methyl bromoacetate (0.44 ml, 4 mmol) was added dropwise to the reaction mixture then warmed to room temperature. The reaction was diluted with 100 ml of ethyl acetate and washed with 0.3N potassium hydrogen sulfate (50 ml), water (2 x 50 ml), and brine. The combined organics were dried over anhydrous sodium sulfate, filtered, and evaporated to afford a gum that was purified by flash chromatography eluting with 3:7 EtOAc/Hex. to give 0.98 g (83%) of the title compound as a white solid.  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  7.15-7.07 (2H, m), 6.98-6.94 (1H, m), 6.88-6.84 (1H, d), 5.62-5.55 (1H, d), 4.71-4.65 (1H, d), 4.65-4.6 (1H, m), 4.33-4.27 (1H, d), 3.96-3.90 (1H, m), 3.78 (3H, s), 3.44-3.37 (1H, m), 1.4 (9H, s).



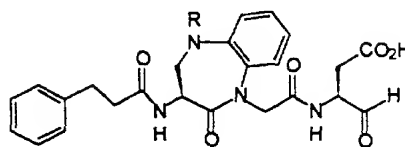
103



104



105



106

- a R = H
- b R = COCH<sub>2</sub>CH<sub>2</sub>Ph
- c R = CH<sub>2</sub>Ph

5 **[2-Oxo-3(S)-(3-phenylpropionylamino)-2,3,4,5-**  
**tetrahydro-benzo[b][1,4]diazepin-1-yl]acetic acid**  
**methyl ester (104a).** Anhydrous hydrogen chloride was  
 bubbled into a solution of (3(S)-tert-  
 10 butoxycarbonylamino-2-oxo-2,3,4,5-tetrahydro-benzo[b]  
 [1,4]diazepin-1-yl)acetic acid methyl ester (103, 1g,  
 2.86 mmol) in 25 ml of ethyl acetate for 2 minutes  
 then stirred for 1 hour at room temperature. The  
 reaction was evaporated to give 2-oxo-3(S)-amino-  
 2,3,4,5-tetrahydrobenzo[b][1,4]diazepin-1-yl acetic  
 acid methyl ester hydrochloride as a white solid.  
 15 The hydrochloride salt and hydrocinnamic acid (0.47 g,  
 3.15 mmol) was dissolved into 20 ml of  
 dimethylformamide and cooled to 0 °C.  
 Diisopropylethylamine (1 ml, 5.72 mmol) was added to  
 the solution followed by the addition of N-  
 20 hydroxybenzotriazole and 1-(3-dimethylaminopropyl)-3-  
 ethylcarbodiimide hydrochloride. After stirring for

18 hours at room temperature, the mixture was diluted with 150 ml of ethyl acetate and washed with 10% sodium hydrogen sulfate, 10% sodium bicarbonate, and brine. The organic layer was dried over anhydrous sodium sulfate, filtered, and evaporated to a crude solid that was purified by flash chromatography eluting with 7:3 ethyl acetate/dichloromethane to afford 600 mg (55%) of the title compound as a white solid. <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.3-6.85 (9H, m), 6.55-6.0 (1H, d), 4.88-4.82 (1H, m), 4.72-4.65 (1H, d), 4.28-4.22 (1H, m), 3.95-3.9 (1H, m), 3.78 (3H, s), 3.65 (1H, br. s), 3.28-3.2 (1H, m), 2.95-2.84 (2H, m), 2.55-2.4 (2H, m).

(3(S)-(3-Phenylpropionylamino)-2-oxo-2,3,4,5-tetrahydrobenzo[b][1,4]diazepin-1-yl)acetic acid (105a). (3(S)-(3-Phenylpropionylamino)-2-oxo-2,3,4,5-tetrahydro-benzo[b][1,4]diazepin-1-yl)acetic acid methyl ester (104a) was dissolved in 90% methanol. Lithium hydroxide hydrate was added to the reaction and the reaction was stirred at room temperature for 4 h. The reaction was evaporated in vacuo to give a white solid. This was dissolved in 20 ml of water and acidified to pH 5 and extracted with ethyl acetate to afford 304 mg (88%) of the title compound as a white solid. <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.5-6.9 (11H, m), 4.92-4.8 (1H, m), 4.7-4.58 (1H, d), 4.38-4.25 (1H, d), 3.88-3.78 (1H, m), 3.45-3.25 (1H, m), 3.05-2.85 (2H, m), 2.55-2.45 (2H, m).

4-Oxo-3(S)-{2-[2-oxo-3(S)-(3-phenylpropionylamino)-2,3,4,5-tetrahydro-benzo[b][1,4]diazepin-1-ylacetylamino]}butyric acid (106a). N-[1-(2-Benzyloxy-

5-oxotetrahydrofuran-3-ylcarbamoyl-methyl)- 2-oxo-  
2,3,4,5-tetrahydro-1H-benzo[b][1,4]diazepin-3-yl]-3-  
phenylpropionamide was prepared from 105a by the  
procedure in example 3, compound H (stepA) to afford  
5 390 mg (93%) of the product as diastereomers. <sup>1</sup>H NMR  
(CD<sub>3</sub>OD) δ 7.58-7.22 (14H, m), 5.78-5.73 (0.5 H, d),  
5.64 (0.5 H, s), 5.0-4.72 (4H, m), 4.54-4.42 (2H, m),  
3.82-3.76 (0.5 H, m), 3.68-3.62 (0.5 H, m), 3.28-3.21  
(0.5H, m), 3.19-3.12 (0.5H, m), 3.07-2.98 (2H, m),  
10 2.78-2.48 (4H, m).

The resulting product was converted to 106a by the  
method described in example 3, compound H (StepD) to  
afford the title compound as a white solid (17%): <sup>1</sup>H  
NMR (CD<sub>3</sub>OD) δ 7.54-6.98 (9H, m), 5.58-5.44 (1H, m),  
15 4.8-4.2 (4H, m), 3.96-3.3 (2H, m), 3.30-3.05 (1H, m),  
2.98-2.25 (5H, m).

[2-Oxo-5-(3-phenylpropionyl)-3(S)-(3-  
phenylpropionylamino)-2,3,4,5-  
tetrahydrobenzo[b][1,4]diazepin-1-yl]acetic acid  
20 methyl ester (104b). Anhydrous hydrogen chloride was  
bubbled into a solution of (3(S)-tert-  
butoxycarbonylamino-2-oxo-2,3,4,5-tetrahydro-  
benzo[b][1,4]diazepin-1-yl)acetic acid methyl ester  
(103, 1g, 2.86mmol) in 25 ml of ethyl acetate for 2  
25 minutes then stirred for 1 hour at room temperature.  
The reaction was evaporated to give 2-oxo-3(S)-amino-  
2,3,4,5-tetrahydrobenzo[b][1,4]diazepin-1-yl acetic  
acid methyl ester hydrochloride as a white solid.  
The hydrochloride salt was suspended into 20 ml of  
30 dichloromethane and cooled to 0 °C. Triethylamine  
(1.6 ml, 11.5 mmol) was added to the suspension  
followed by the dropwise addition of dihydrocinnamoyl

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chloride (0.9 ml, 6 mmol). The mixture was warmed to room temperature and stirred for 18 hours. The mixture was diluted with 25 ml of dichloromethane and washed twice with 50 ml of water and once with 50 ml of brine. The organic layer was dried over anhydrous sodium sulfate, filtered, and evaporated to give a viscous, yellow oil that was purified by flash chromatography eluting with 1:1 ethyl acetate/dichloromethane to afford 1.35 g (92%) of the title product as a white solid. <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.45-7.02 (14 H, m), 6.37-6.32 (1H, d), 4.78-4.72 (1H, m), 4.52-4.3 (3H, m), 3.82-3.77 (1H, m), 3.74 (3H, s), 3.03-2.87 (4H, m), 2.58-2.45 (2H, m), 2.45-2.35 (1H, m), 2.25-2.16 (1H, m).

**[2-Oxo-5-(3-phenylpropionyl)-3-(3(S)-phenylpropionylamino)-2,3,4,5-tetrahydrobenzo[b][1,4]diazepin-1-yl]acetic acid (105b).** [2-Oxo-5-(3-phenylpropionyl)-3-(3-phenylpropionylamino)-2,3,4,5-tetrahydrobenzo[b][1,4]diazepin-1-yl]acetic acid methyl ester (**104b**; 680 mg, 1.32 mmol) was hydrolyzed by the procedure in example 105a to afford 645 mg (98%) of the title compound as a white solid. <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.58 (1H, br. s), 7.5-7.42 (1H, m), 7.35-6.95 (14H, m), 4.95-4.88 (1H, m), 4.64-4.55 (1H, d), 4.54-4.45 (1H, t), 4.15-4.05 (1H, d), 3.75 (1H, m), 3.05-2.75 (4H, m), 2.58-2.45 (2H, m), 2.45-2.28 (1H, m), 2.25-2.14 (1H, m).

**2-Oxo-3(S)-{2-[2-oxo-5-(3-phenylpropionyl)-3(S)-(3-phenyl-propionyl-amino)-2,3,4,5-tetrahydrobenzo[b][1,4]diazepin-1-yl]**

**acetylamino}butyric acid (106b).** [2-Oxo-5-(3-phenylpropionyl)-3-(3-phenylpropionylamino)-2,3,4,5-tetrahydrobenzo[b][1,4]diazepin-1-yl]acetic acid and 3-amino-4-oxobutyric acid tert-butylester

5 semicarbazone were coupled by the procedure in example 3, compound K (step A) to give 350 mg (85%) of a white solid. <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 9.05 (1H, br. s), 7.58-7.55 (1H, d), 7.5-7.35 (1H, m), 7.35-6.95 (14 H, m), 6.75-6.72 (1H, d), 6.25 (1H, br. s), 5.25 (1H, br. s),  
10 4.95-4.88 (1H, m), 4.8-4.72 (1H, m), 4.55-4.4 (2H, m), 3.92-3.88 (1H, d), 3.73-3.68 (1H, m), 2.95-2.8 (4H, m), 2.8-2.72 (1H, m), 2.62-2.55 (1H, m), 2.55-2.45 (2H, m), 2.4-2.32 (1H, m), 2.2-2.12 (1H, m), 1.45 (9H, s).

15 4-Oxo-3-{2-[2-oxo-5-(3-phenylpropionyl)-3-(3-phenylpropionyl -amino)-2,3,4,5-tetrahydrobenzo[b][1,4]diazepin-1-yl]-acetyl-amino}butyric acid tert-butyl ester semicarbazone was deprotected as described in example 3, compound K  
20 (step C) to give 118 mg (47%) of the title compound as a white solid. <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 7.48-6.95 (14 H, m), 4.65-4.15 (6H, m), 3.5-3.4 (1H, m), 2.85-2.72 (4H, m), 2.65-2.5 (1H, m), 2.5-2.34 (3H, m), 2.34-2.15 (2H, m).

**[5-Benzyl-2-oxo-3(S)-(3-phenylpropionylamino)-2,3,4,5-tetrahydro -benzo[b][1,4]diazepin-1-yl]acetic acid methyl ester (104c).** [2-Oxo-3-(3-phenylpropionylamino)-2,3,4,5-tetrahydrobenzo-  
25 [b][1,4]diazepin-1-yl]acetic acid methyl ester (104a; 500 mg, 1.31 mmol), calcium carbonate (155 mg, 1.58  
30 mmol), and benzyl bromide (170 μl, 1.44 mmol) were taken into 10 ml of dimethylformamide and heated to 80 °C for 8 hours. The mixture was diluted with 150 ml

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of ethyl acetate and washed 4 times with 50 ml of water. The organic layer was dried over anhydrous sodium sulfate, filtered, and evaporated to give a viscous, yellow oil that was purified by flash chromatography eluting with dichloromethane/ethyl acetate (8:2) to give 460 mg (75%) of the title compound as a white solid. <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.34-7.05 (14 H, m), 6.32-6.28 (1H, d), 4.84-4.76 (1H, d), 4.76-4.70 (1H, m), 4.43-4.37 (1H, d), 4.26-4.18 (1H, d), 4.06-4.00 (1H, d), 3.79 (3H, s), 3.45-3.37 (1H, m), 3.02-2.95 (1H, m), 2.90-2.82 (2H, m), 2.5-2.34 (2H, m).

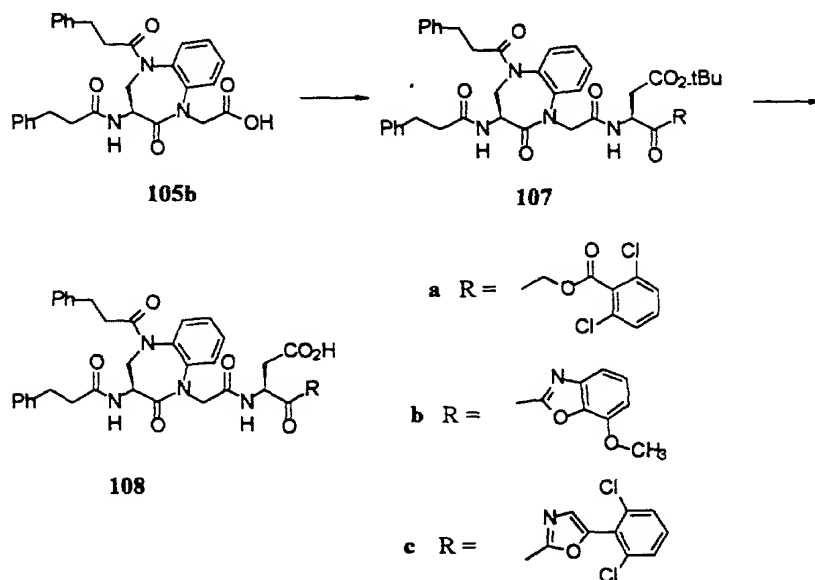
**[5-Benzyl-2-oxo-3(S)-(3-phenylpropionylamino)-2,3,4,5-tetrahydro -benzo[b][1,4]diazepin-1-yl]acetic acid (105c)** was prepared by the hydrolysis of the ester (102c) by the procedure reported in example 105a to give 450 mg (98%) of the title compound as a white solid: <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 7.5-7.05 (14 H, m), 6.4 (1H, br. s), 4.85-4.55 (2H, m), 4.5-4.21 (2H, m), 4.12-3.92 (1H, d), 3.45-3.3 (1H, m), 3.1-2.8 (3H, m), 2.55-2.28 (3H, m).

**3(S)-{2-[5-Benzyl-2-oxo-3-(3(S)-phenylpropionylamino)-2,3,4,5-tetrahydrobenzo[b][1,4]diazepin-1-yl]-acetyl-amino}-4-oxobutyric acid (106c).** [5-Benzyl-2-oxo-3(S)-(3-phenylpropionylamino)-2,3,4,5-tetrahydrobenzo[b][1,4]diazepin-1-yl]acetic acid and 3(S)-amino-4-oxobutyric acid tert-butylester semicarbazone were coupled by the procedure in example 3, compound K (step A) and to afford 260 mg (85%) of a white solid: <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 7.35-7.0 (15 H, m), 4.94-4.88 (1H, m), 4.68-4.58 (1H, d), 4.57-4.52 (1H, m), 4.41-4.34



(1H, d), 4.3-4.23 (1H, d), 4.1-4.04 (1H, d), 3.18-3.11 (1H, m), 3.09-2.98 (1H, m), 2.78-2.72 (2H, t), 2.65-2.57 (1H, m), 2.42-2.33 (3H, m).

3(S)-{2-[5-Benzyl-2-oxo-3(S)-(3-phenylpropionylamino)-  
2,3,4,5-tetrahydrobenzo[b][1,4]diazepin-1-yl]-  
acetyl-amino}-4-oxobutyric acid tert-butyl ester  
semicarbazone was deprotected as described in example  
3, compound K (step C) to give 168 mg (81%) of the  
title compound as a white solid. <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ  
7.37-7.0 (14H, m), 4.75-4.62 (1H, m), 4.6-4.45 (2H,  
m), 4.4-4.21 (2H, m), 4.15-3.95 (2H, m), 3.15-3.0 (2H,  
m), 2.82-2.67 (2H, m), 2.65-2.52 (1H, m), 2.5-2.32  
(3H, m).



2,6-Dichlorobenzoic acid 4-tert-butoxycarbonyl-2-oxo-  
3(S)-{2-[2-oxo-5-(3-phenylpropionyl)-3(S)-(3-  
phenylpropionylamino)-2,3,4,5-tetrahydro-  
benzo[b][1,4]diazepin-1-yl]acetyl-amino}butyl ester  
(107a). The resulting semicarbazone was prepared by  
the coupling of compound 105b and t-butyl 3-

(allyloxycarbonylamino)-4-oxo-5-(2,6-dichlorobenzoyl-oxy)pentanoate (WO 93 16710) as described in compound 56a to give 256 mg (58%) of the title compound as a white solid. <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.45-7.04 (17H, m), 6.45-6.34 (2H, m), 5.28-5.21 (1H, m), 5.1-5.0 (1H, m), 4.95-4.90 (1H, m), 4.75-4.70 (1H, m), 4.55-4.44 (1H, m), 4.32-4.22 (1H, dd), 3.99-3.85 (1H, dd), 3.85-3.76 (1H, m), 3.06-2.83 (5H, m), 2.83-2.74 (1H, m), 2.6-2.44 (2H, m), 2.43-2.33 (1H, m), 2.24-2.15 (1H, m), 1.45 (9H, s).

2,6-Dichlorobenzoic acid 4-carboxy-2-oxo-3(S)-{2-[2-oxo-5-(3-phenylpropionyl)-3(S)-(3-phenylpropionylamino)-2,3,4,5-tetrahydrobenzo[b][1,4]diazepin-1-yl]acetylamino}butyl ester (108a) was prepared from 107a by the method described for compound 57a which afforded 156 mg (68%) of the title compound as a white solid. <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 7.5-6.9 (17H, m), 5.16-5.02 (1H, dd), 4.88-4.71 (2H, m), 4.62-4.44 (2H, m), 4.42-4.28 (2H, m), 4.27-4.18 (1H, m), 3.47-3.41 (1H, m), 2.90-2.60 (5H, m), 2.46-2.4 (2H, m), 2.39-2.18 (2H, m).

4-(7-Methoxybenzoxazol-2-yl)-4-oxo-3(S)-{2-[2-oxo-5-(3-phenylpropionyl)-3(S)-(3-phenylpropionylamino)-2,3,4,5-tetrahydrobenzo[b][1,4]diazepin-1-yl]-acetylamino} butyric acid tert-butyl ester (107b). 4(R,S)-Hydroxy-4-(7-methoxybenzoxazol-2-yl)-3(S)-{2-[2-oxo-5-(3-phenylpropionyl)-3(S)-(3-phenylpropionylamino)-2,3,4,5-tetrahydro[b][1,4]diazepin-1-yl-acetylamino} butyric acid tert-butyl ester was prepared from 105b and 66a by the method described in example 5, compound 67 to

give 56% of a white solid:  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  7.72-6.78 (19H, m), 6.37-6.28 (1H, m), 5.17-5.08 (0.5H, m), 4.92-4.82 (0.5H, m), 4.81-4.6 (1H, m), 4.6-4.35 ((3H,m), 4.05-3.9 (1H, m), 3.95 (3H, s), 3.82-3.7 (1H, m), 2.96-2.05 (10H, m), 1.45 (4.5H, s), 1.38 (4.5H, s).

The resulting product was converted to **107b** by the method described in example 5, compound **68a** to give the title compound (56%) as a white solid.  $^1\text{H}$  NMR

( $\text{CD}_3\text{OD}$ )  $\delta$  7.62-6.8 (17H, m), 5.64-5.58 (0.5H, t), 5.52-5.46 (0.5H, t), 4.62-4.47 (2H, m), 4.40-4.32 (1H, m), 3.9 (1.5H, s), 3.88 (1.5 H, s), 3.43-3.37 (1H, m), 3.0-2.92 (1H, m), 2.90-2.62 (6H, m), 2.5-2.4 (2H, m), 2.28-2.15 (2H, m), 1.32 (4.5H, s), 1.25 (4.5H, s).

**4-(7-Methoxybenzoxazol-2-yl)-4-oxo-3(S)-{2-[2-oxo-5-(3-phenylpropionyl)-3(S)-(3-phenylpropionylamino)-2,3,4,5-tetrahydrobenzo[b][1,4]diazepin-1-yl]-acetylamino}** butyric acid (**108b**) was prepared by the method described in example 5, compound **69a** to give

the title compound (50%) as a white solid.  $^1\text{H}$  NMR ( $\text{CD}_3\text{OD}$ )  $\delta$  7.41-6.88 (17H, m), 5.6-5.55 (0.5H, t), 5.48-5.43 (0.5H, t), 4.64-4.45 (2H, m), 4.45-4.30 (1H, m), 3.93 (1.5H, s), 3.90 (1.5H, s), 3.47-3.34 (1H, m), 3.10-2.85 (2H, m), 2.84-2.63 (5H, m), 2.6-2.4 (2H, m), 2.3-2.1 (2H, m).

**4-[5-(2,6-Dichlorophenyl)oxazol-2-yl]-4-oxo-3(S)-{2-[2-oxo-5-(3-phenylpropionyl)-3(S)-(3-phenylpropionylamino)-2,3,4,5-tetrahydrobenzo[b][1,4]diazepin-1-yl]-acetylamino}**

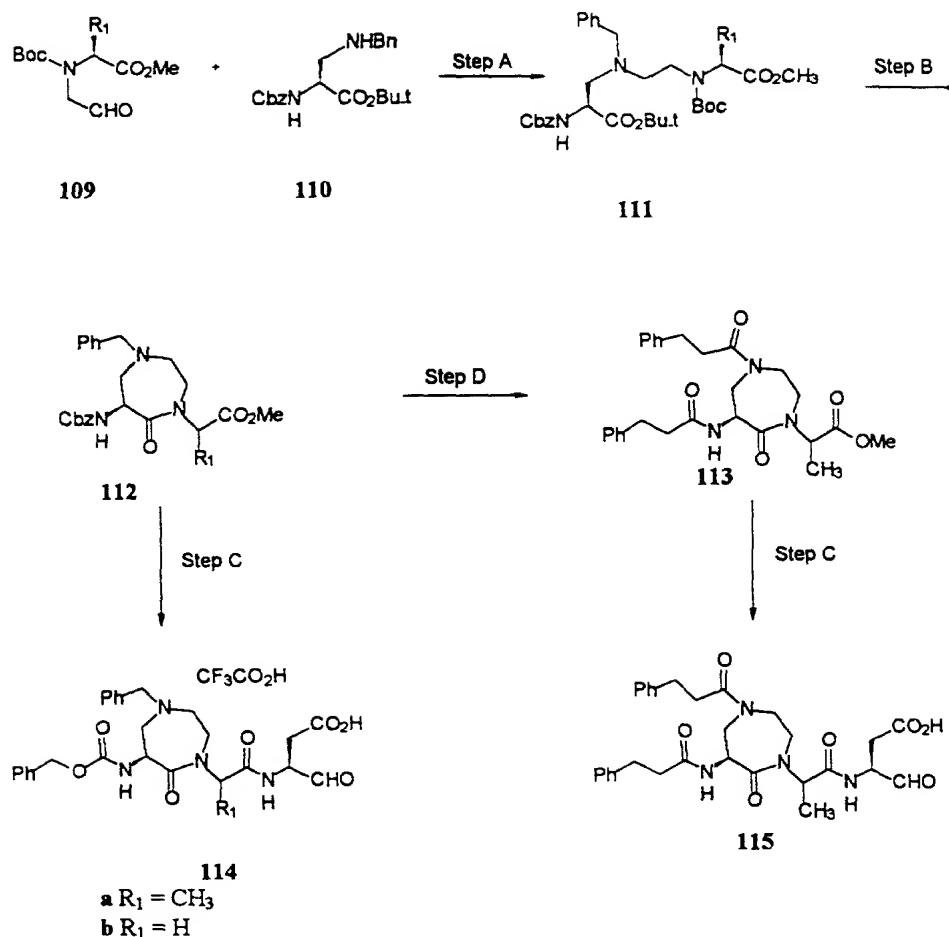
**butyric acid tert-butyl ester (107c).** **4-[5-(2,6-Dichlorophenyl)oxazol-2-yl]-4(R,S)-hydroxy-3(S)-{2-[2-**

oxo- 5-(3-phenylpropionyl)-3(S)-(3-phenylpropionylamino)-2,3,4,5-tetrahydrobenzo[b][1,4]diazepin-1-yl]-acetylamino} butyric acid tert-butyl ester was prepared from 106c and 99 by a similar method as described for compound 67a in example 5 to give 72% of a white solid. <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.71-7.64 (1H, m), 7.58-7.42 (2H, m), 7.42-6.92 (15H, m), 6.5-6.37 (2H, m), 5.15-5.04 (1H, m), 4.88-4.68 (2H, m), 4.57-4.37 (2H, m), 4.28-4.13 (1H, m), 3.87-3.64 (2H, m), 3.04-2.80 (4H, m), 2.76-2.68 (1H, m), 2.67-2.42 (3H, m), 2.41-2.31 (1H, m), 2.22-2.12 (1H, m), 1.45 (9H, s).

The resulting product was converted to 107c by a similar method as described for compound 68a in example 5 to give the title compound in quantitative yield as a white solid. <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.47-6.98 (18H, m), 6.52-6.42 (1H, d), 5.6-5.52 (1H, m), 4.78-4.71 (1H, m), 4.52-4.40 (2H, m), 4.03-3.94 (0.67H, m), 3.94-3.85 (0.33H, m), 3.85-3.75 (1H, m), 3.45-3.33 (1H, m), 3.08-2.98 (1H, m), 2.97-2.84 (4H, m), 2.55-2.43 (2H, m), 2.43-2.32 (1H, m), 2.23-2.13 (1H, m), 1.35 (9H, s).

4-[5-(2,6-Dichlorophenyl)oxazol-2-yl]-4-oxo-3(S)-{2-[2-oxo-5-(3-phenylpropionyl)-3(S)-(3-phenylpropionylamino)-2,3,4,5-tetrahydrobenzo[b][1,4]diazepin-1-yl]-acetylamino} butyric acid (108c) was prepared from 107c by a similar method as described for compound 69a in example 5 to give 72% the title compound as a white solid. <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 7.58-7.0 (18H, m), 5.62-5.53 (0.67H, m), 5.52-5.47 (0.33H, m), 4.68 (3H, m), 3.54-3.42 (1H, m), 3.1-2.92 (2H, m), 2.88-2.68 (5H, m),

2.63-2.45 (2H, m) 2.40-2.22 (2H, m).



3 (S) - { 2 (R, S) - [ 4 - Benzyl - 7 - oxo - 6 (S) - (N - benzyloxycarbonylamino) - [ 1, 4 ] diazepan - 1 - yl ] - propionylamino } - 4 - oxo - butyric acid trifluoroacetic acid salt (114a):

**Step A.** To a solution of tert-butyl-2-N-benzyloxycarbonyl-3-N-benzyl-(S)-2,3-diaminopropionate (110; 0.85 g, 2.2 mmol), 3-(N-tert-butoxycarbonyl)amino-2-methyl-5-oxo-pentanoic acid methyl ester (109a; 0.65 g, 2.7 mmol), acetic acid (0.1 mL, 1.8 mmol), sodium acetate (0.36 g, 2

mmol) and 4 Å molecular sieves (1 g) in methanol (45 mL), was added sodium cyanoborohydride (0.33 g, 5.3 mmol). The mixture was stirred overnight at 25 °C then filtered through Celite and concentrated under reduced pressure. The residue was dissolved in 1 N NaOH and extracted with ethyl acetate (3 x 40 mL). The organic layer was dried (MgSO<sub>4</sub>), filtered and evaporated to give an oil. Chromatography (silica-gel, 4:1 hexane: ethyl acetate as eluent) gave 0.92 g (68% yield) of **111a** as an oil.

**Step B.** The above material was dissolved in dichloromethane (3 mL) cooled to 0 °C and treated with a 25% solution of trifluoroacetic acid in dichloromethane (20 mL) then allowed to warm to 25 °C and stir until the reaction was judged complete by TLC (4:1 hexane: ethyl acetate). The solvent was removed under reduced pressure and the residue dried under vacuum then dissolved in dichloromethane (40 mL) and treated with 4-methylmorpholine (1 mL, 9 mmol), HOBT (0.2g, 1.5 mmol) and EDC (0.61 g, 3.2 mmol). The resulting mixture was stirred overnight at 25 °C then diluted with dichloromethane and washed with water. The organic layer was dried (MgSO<sub>4</sub>), filtered and evaporated to give an oil.

Chromatography (silica-gel, 3:2 hexane: ethyl acetate) gave 0.49 g (74% yield) of **112a** as a viscous oil.

**Step C.** A solution of 2(R,S)-[4-benzyl-7-oxo-6(S)-(N-benzyloxycarbonylamino)-[1,4]diazepan-1-yl]-propionic acid methyl ester (**112a**; 0.15 g, 0.32 mmol) was dissolved in methanol and treated with 1 M LiOH (0.32 mL) and stirred 5.5 hours at 25 °C then evaporated to dryness. The residue was azeotroped with ethanol (2 x 10 mL), acetonitrile (2 x 10 mL),

benzene (2 x 10 mL) then dried under vacuum. The resulting residue was converted to 114a by a method similar to that described in example 3, compound K (steps A, B, and C) and purified by reverse phase (C18 column) HPLC using 0.1%TFA:water/  
5 0.1%TFA:acetonitrile as eluent. to give 17 mg (10% yield) of a viscous oil: <sup>1</sup>H NMR (500 MHz, CD<sub>3</sub>OD) δ 1.15 (m, 3 H), 2.30- 2.70 (m, 6 H), 2.72- 2.95 (bm, 6 H), 3.30- 3.80 (m, 4 H), 4.10 (m, 1 H), 4.40 (m, 4  
10 H), 4.95 (m, 1H) 6.95- 7.10 (bs, 5 H), and 7.12- 7.20 ppm (bs, 5 H).

3(S)-{2-[4-Benzyl-7-oxo-6(S)-(N-benzyloxycarbonylamino)-[1,4]diazepan-1-yl]-acetylamino}-4-oxo-butyric acid trifluoroacetic acid  
15 salt (114b) was prepared from 109b by a similar method described for the synthesis of 114a to give 85 mg of viscous oil: <sup>1</sup>H NMR (500 MHz, CD<sub>3</sub>OD) δ 1.20 (d, J = 7 Hz, 3 H), 2.28 (m, 2 H), 2.60 (m, 2 H), 3.18 (bs, 6 H), 3.35- 3.45 (m, 2 H), 3.60- 3.95 (m, 2  
20 H), 4.15 (m, 1 H), 4.32 (m, 1 H), 4.42 (m, 1 H), 5.00 (bm, 2 H), 7.20 (bs, 5 H), and 7.40 ppm (bs, 5 H); <sup>19</sup>F NMR (470 MHz, CD<sub>3</sub>OD) δ -10.72 ppm (s, 3 F).

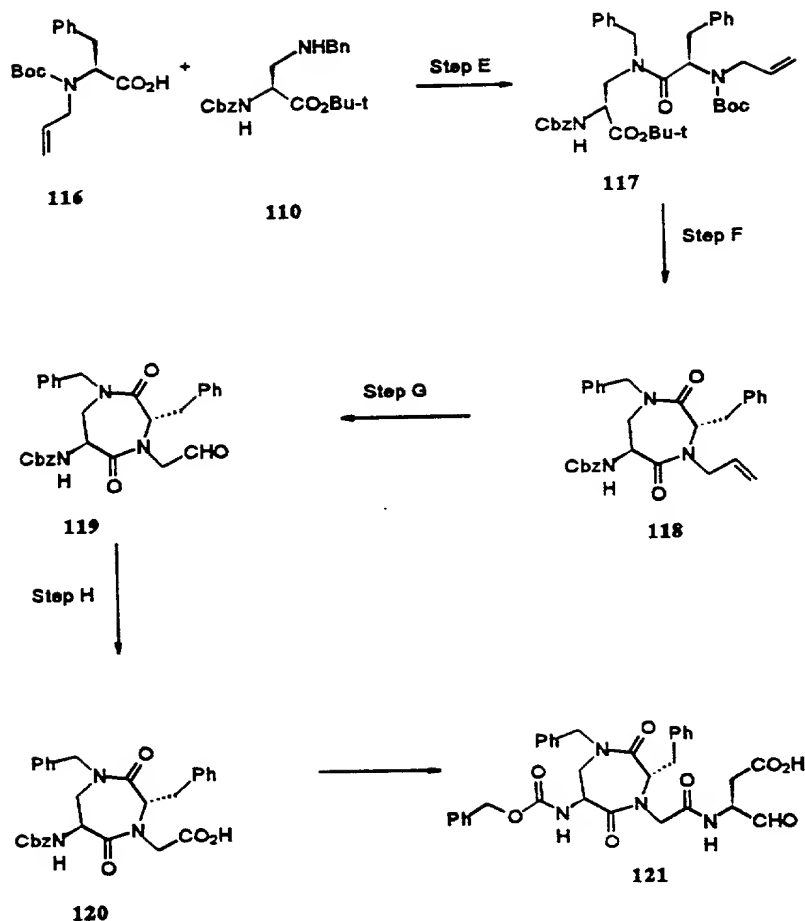
4-Oxo-3(S)-{2(R,S)-[7-oxo-4-(3-phenyl-propionyl)-6(S)-(3-phenyl-propionylamino)-[1,4]diazepan-1-yl]-propionylamino}-butyric acid (115):  
25

**Step D.** A suspension of 2(R,S)-[4-benzyl-7-oxo-6(S)-(N-benzyloxycarbonylamino)-[1,4]diazepan-1-yl]-propionic acid methyl ester (112b; 0.22 g, 0.49 mmol) and 20% Pd(OH)<sub>2</sub> on carbon (50 mg) in ethanol was  
30 stirred under hydrogen atmosphere for 7 hours. The solvent was evaporated under reduced pressure and the

residue dissolved in dichloromethane (20 mL) then  
treated with triethylamine (1 mL) and  
dihydrocinnamoyl chloride (170 mg, 1 mmol). The  
resulting mixture was allowed to stir overnight then  
5 diluted with ethyl acetate and washed with 1 N NaOH.  
The organic layer was dried ( $\text{MgSO}_4$ ), filtered and  
evaporated to give an oil. Chromatography (silica-  
gel, 4:1 hexane: ethyl acetate) gave 0.175 g (75%  
yield) of **113** as an oil.

10 **Step C.** A 0.15 g sample of **113** (0.32 mmol) was  
dissolved in methanol, treated with 1 M LiOH (0.32  
mL), stirred at 40 °C overnight then evaporated to  
dryness. The residue was azeotroped with ethanol (2  
x 10 mL), acetonitrile (2 x 10 mL), benzene (2 x 10  
15 mL) then dried under vacuum. The resulting residue  
was converted to **115** by a method similar to that  
described in example 3, compound **K** (steps A, B, and  
C).





3-{2-[2,4-Dibenzyl-3,7-dioxo-6-(N-benzyloxycarbonylamino)-[1,4]diazepan-1-yl]-acetylamino}-4-oxo-butyric acid (121):

- 5 **Step E.** A solution of tert-butyl-2-N-carbobenzoxy-3-N-benzyl-(S)-2,3-diaminopropionate (110; 1.77 g, 4.6 mmol), N-allyl-N-tert-butoxycarbonyl-(S)-phenylalanine (116; 1.04 g, 4.8 mmol), HOBT (0.74 g, 5.5 mmol) and EDC (1.33 g, 6.9 mmol) in
- 10 dichloromethane (50 mL) was allowed to stir at 25 °C for 16 h then diluted with dichloromethane (100 mL) and washed with water. The organic layer was dried (MgSO<sub>4</sub>), filtered and evaporated to give an oil. Chromatography (silica-gel, 85: 15 hexane: ethyl

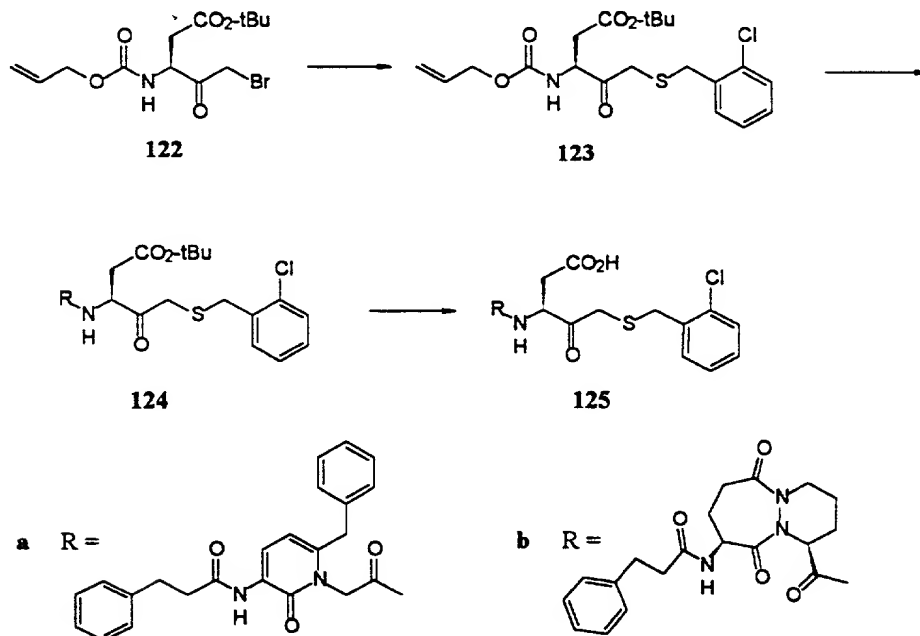
acetate) gave 1.34 g (43% yield) of 117 as a colorless viscous oil.

5 **Step F.** A 1.34 g sample of 117 was dissolved in dichloromethane (3 mL) and treated with a 50% solution of trifluoroacetic acid in dichloromethane (20 mL). After 1.5 h, the solvent was removed under reduced pressure and the residue dried under vacuum then dissolved in dichloromethane (50 mL) and combined with 4-methylmorpholine (0.2 mL, 2 mmol),  
10 HOBT (0.27 g, 2 mmol) and EDC (0.8 g, 4 mmol). The mixture was stirred overnight at 25 °C then diluted with dichloromethane and washed with water. The organic layer was dried (MgSO<sub>4</sub>), filtered and evaporated to give an oil. Chromatography (silica-gel, 7:3 hexane: ethyl acetate) gave 0.8 g (80%  
15 yield) of 118 as a viscous oil.

**Step G.** A 0.8 g sample of 118 was dissolved in methanol (40 mL), cooled to -78 °C and saturated with ozone until the solution was blue in color. The  
20 excess ozone was removed by purging with argon then dimethylsulfide (5 mL) was added and the mixture allowed to warm to 25 °C and stir 3 h. Solvent removal and chromatography (silica-gel, 1:1 hexane: ethyl acetate ) gave 0.74 g (74% yield) of 119 as a  
25 white solid.

**Step H.** A 0.2 g sample (0.4 mmol) of 119 was dissolved in acetone (25 mL), cooled to 0 °C and treated dropwise with a solution of Jones reagent until the orange color persisted. 2-Propanol (5 mL)  
30 was then added to the mixture and the resulting solution filtered through Celite and washed with acetone. Solvent removal gave a green-white solid that was dried under vacuum to give 120. The resulting residue was converted to 121 by a method

similar to that described in example 3, compound K (steps A, B, and C). Chromatography (SiO<sub>2</sub>, 95: 4.5: 0.5 dichloromethane: methanol: acetic acid eluent) gave 85 mg (53% yield) of cream colored solid which was identified as 3-{2-[2,4-dibenzyl-3,7-dioxo-6-(N-benzyloxycarbonylamino)-[1,4]diazepan-1-yl-acetylamino}-4-oxo-butyrac acid (121) on the basis of the following spectral data: <sup>1</sup>H NMR (500 MHz, CD<sub>3</sub>OD) δ 2.38 (m, 1 H), 2.45 (m, 1 H), 3.21 (bs, 2 H), 3.32-3.39 (bm, 6 H), 3.85 (m, 1 H), 4.05 (m, 1 H), 4.21 (bm, 1 H), 4.31 (bs, 1 H), 4.45 (dm, J = 11 Hz, 1 H), 4.95 (bs, 4 H), 7.20 (bs, 5 H), and 7.33- 7.45 ppm (m, 5 H); <sup>19</sup>F NMR (470 MHz, CD<sub>3</sub>OD) d -10.62 ppm (s, 3 F).



**t-Butyl (3S) N-(allyloxycarbonyl)-3-amino-5-(2-chlorophenylmethylthio)-4-oxo-pentanoate (123).** Potassium fluoride (273mg, 4.70mmol) and then 2-chlorophenylmethyl thiol (373mg, 2.35mmol) were added

to a stirred solution of (3*S*) t-butyl N-(allyloxycarbonyl)-3-amino-5-bromo-4-oxo-pentanoate (122; 749mg, 2.14mmol; WO 93 16710) in dimethylformamide (20ml). The mixture was stirred for 3.5h, quenched with water (50ml) and extracted with ethyl acetate (2 x 50ml). The combined organic extracts were washed with water (4 x 50ml) then brine (50ml). They were dried (MgSO<sub>4</sub>) and concentrated to afford an oil which was purified by flash chromatography (10-35% ethyl acetate / hexane) to afford 832 mg (91%) of a colourless solid: mp. 45-6 °C;  $[\alpha]_D^{20}$  -19.0° (c 1.0, CH<sub>2</sub>Cl<sub>2</sub>); IR (film) 3340, 2980, 2935, 1725, 1712, 1511, 1503, 1474, 1446, 1421, 1393, 1368, 1281, 1244, 1157, 1052, 1040, 995, 764, 739; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.36 (2H, m), 7.21 (2H, m), 5.91 (2H, m), 5.27 (2H, m), 4.76 (1H, m), 4.59 (2H, d), 3.78 (2H, s), 3.36 (2H, m), 2.91 (1H, dd), 2.74 (1H, dd), 1.43 (9H, s). Anal. Calcd for C<sub>20</sub>H<sub>26</sub>ClNO<sub>5</sub>S: C, 56.13; H, 6.12; N, 3.27; S, 7.49. Found: C, 56.08; H, 6.11; N, 3.26; S, 7.54. MS (C.I.) 430/28 (M<sup>+</sup> + 1, 3%), 374/2 (100).

**t-Butyl (3*S*) 3(2(6-benzyl-1,2-dihydro-2-oxo-3(3-phenylpropionylamino)-1-pyridyl)acetyl-amino-5-(2-chlorophenylmethylthio)-4-oxopentanoate (124a).** 6-Benzyl-1,2-dihydro-2-oxo-3-(3-phenylpropionylamino)-pyridyl acetic acid (52b; 300mg, 0.76mmol) in THF (7ml) was stirred with 1-hydroxybenzotriazole (205mg, 1.52mmol) and 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride). After 3 min, water (12 drops) was added and the mixture stirred 10min then treated with t-butyl (3*S*) N-(allyloxycarbonyl)-3-amino-5-(2-chlorophenylmethylthio)-4-oxopentanoate

(123) (325mg, 0.76mmol), bis (triphenylphosphine) palladium II chloride (20mg) and tributyltin hydride (0.6ml, 2.28mmol). The mixture was stirred for 5h at room temperature, poured into ethyl acetate and washed with aqueous 1M HCl (x2), aqueous sodium bicarbonate, brine, dried (MgSO<sub>4</sub>) and concentrated. The residue was triturated with pentane and the supernatant discarded. Chromatography (silica gel, 50% ethyl acetate/hexane) afforded a colourless foam (439mg, 81%):  $[\alpha]_D^{21}$  -18.3 ° (c 0.5, CH<sub>2</sub>Cl<sub>2</sub>); IR (KBr) 3356, 3311, 1722, 1689, 1646, 1599, 1567, 1513, 1367, 1154; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 8.39 (1H, d), 8.23 (1H, s), 7.24 (14H, m), 6.16 (1H, d), 4.95 (1H, m), 4.63 (2H, m), 4.02 (2H, s), 3.74 (2H, s), 3.27 (2H, s), 2.85 (6H, m), 1.40 (9H, s). Anal. Calcd for C<sub>39</sub>H<sub>42</sub>ClN<sub>3</sub>O<sub>6</sub>S: C, 65.39; H, 5.91; N, 5.87. Found: C, 65.51; H, 5.99; N, 5.77.

**t-Butyl[3*S*(1*S*,9*S*)]-3-(6,10-dioxo-1,2,3,4,7,8,9,10-octahydro)-9-(3-phenylpropionylamino)-6H-pyridazine[1,2-*a*][1,2]diazepine-1-carboxamido-5-(2-chlorophenylmethylthio)-4-oxopentanoate (124b)** was prepared by a similar method as 124a from the thioether 123 and 3*S*(1*S*,9*S*)-3-(6,10-dioxo-1,2,3,4,7,8,9,10-octahydro)-9-(3-phenylpropionylamino)-6H-pyridazino[1,2-*a*][1,2]diazepine-1-carboxylic acid (45a) to afford 452mg (50%) of colourless foam: mp 55-7 °C;  $[\alpha]_D^{22}$  -94.0° (c 0.12, CH<sub>2</sub>Cl<sub>2</sub>); IR (KBr) 3288, 2934, 1741, 1722, 1686, 1666, 1644, 1523, 1433, 1260, 1225, 1146, 757; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.35 (3H, m), 7.20 (7H, m), 6.46 (1H, d), 5.21 (1H, m), 4.97 (2H, m), 4.56 (1H, m), 3.75 (2H, s), 3.25 (3H, m), 2.93 (5H, m), 2.71 (1H,

dd), 2.55 (2H, m), 2.30 (1H, m), 1.92 (3H, m), 1.66  
(2H, m), 1.42 (9H, s). Anal. Calcd for  $C_{35}H_{43}ClN_4O_7S$ .  
0.25H<sub>2</sub>O: C, 59.73; H, 6.23; Cl, 5.04; N, 7.96; S,  
4.56. Found: C, 59.73; H, 6.19; Cl, 5.10; N, 7.79;  
5 S, 4.58. MS (-FAB) 697 (M-1, 100).

(3S) 3(2(6-Benzyl-1,2-dihydro-2-oxo-3-(3-  
phenylpropionylamino)-1-  
pyridyl)acetyl-amino-5-(2-chlorophenylmethylthio)-4-  
oxopentanoic acid (125a). t-Butyl-3(2(6-benzyl-1,2-  
10 dihydro-2-oxo-3-(3-phenylpropionylamino)-1-  
pyridyl)acetyl-amino-5-(2-chlorophenylmethylthio)-4-  
oxopentanoate (124a) (400mg, 0.56mmol) in  
dichloromethane (3ml) at 0 °C was treated with  
trifluoroacetic acid (3ml) and stirred at 0 °C for 1h  
15 and room temperature for 0.5h. The solution was  
concentrated then redissolved in dichloromethane and  
reconcentrated. This procedure was repeated three  
times. The residue was stirred in ether for 1hr and  
filtered to yield a colourless solid (364mg, 99%):  
20 mp. 165-7 °C;  $[\alpha]_D^{22}$  -27.7 ° (c 0.2, CH<sub>2</sub>Cl<sub>2</sub>); IR (KBr)  
3289, 1712, 1682, 1657, 1645, 1593, 1562, 1527, 1497,  
1416, 1203, 1182; <sup>1</sup>H NMR (CDCl<sub>3</sub>) d 8.47 (1H, d), 8.21  
(1H, s), 7.70 (1H, d), 7.22 (14H, m), 6.24 (1H, d),  
5.03 (1H, m), 4.65 (2H, m), 4.06 (2H, s), 3.69 (2H,  
25 m), 3.23 (2H, m), 2.88 (6H, m).

[3S(1S, 9S)]-3-(6,10-dioxo-1,2,3,4,7,8,9,10-  
octahydro)-9-(3-phenylpropionyl-  
amino)-6H-pyridazine[1,2-a][1,2]diazepine-1-  
carboxamido-5-(2-chlorophenyl-methylthio)-4-  
30 oxopentanoic acid (125b), was prepared by a similar  
method as 125a from the t-butyl ester 124b to afford

362mg (93%) of colourless powder: mp 76-80 °C;  $[\alpha]_D^{21}$   
-134 ° (c 0.10, MeOH); IR (KBr) 3309, 2935, 1725,  
1658, 1528, 1445, 1417, 1277, 1219, 1175;  $^1\text{H}$  NMR ( $\text{D}_6$ -  
DMSO)  $\delta$  8.80 (1H, d), 8.19 (1H, d), 7.31 (9H, m),  
5 5.09 (1H, m), 4.74 (1H, m), 4.63 (1H, m), 4.35 (1H,  
m), 3.76 (2H, m), 3.28 (3H, m), 2.80 (5H, m), 2.52  
(4H, m), 2.16 (2H, m), 1.90 (3H, m). Anal. Calcd for  
 $\text{C}_{31}\text{H}_{35}\text{Cl}_2\text{N}_4\text{O}_7\text{S} \cdot 0.25\text{H}_2\text{O}$ : C, 57.49; H, 5.53; N, 8.65; S,  
4.95. Found: C, 57.35; H, 5.43; N, 8.45; S, 4.88.  
10 MS (-FAB) 641 (M-1, 100).

The data of the examples above demonstrate  
that compounds according to this invention display  
inhibitory activity towards IL-1 $\beta$  Converting Enzyme.

15 Insofar as the compounds of this invention  
are able to inhibit ICE in vitro and furthermore, may  
be delivered orally to mammals, they are of evident  
clinical utility for the treatment of IL-1 mediated  
diseases. These tests are predictive of the  
20 compounds ability to inhibit ICE in vivo.

While we have described a number of  
embodiments of this invention, it is apparent that  
our basic constructions may be altered to provide  
other embodiments which utilize the products and  
25 processes of this invention. Therefore, it will be  
appreciated that the scope of this invention is to be  
defined by the appended claims, rather than by the  
specific embodiments which have been presented by way  
of example.